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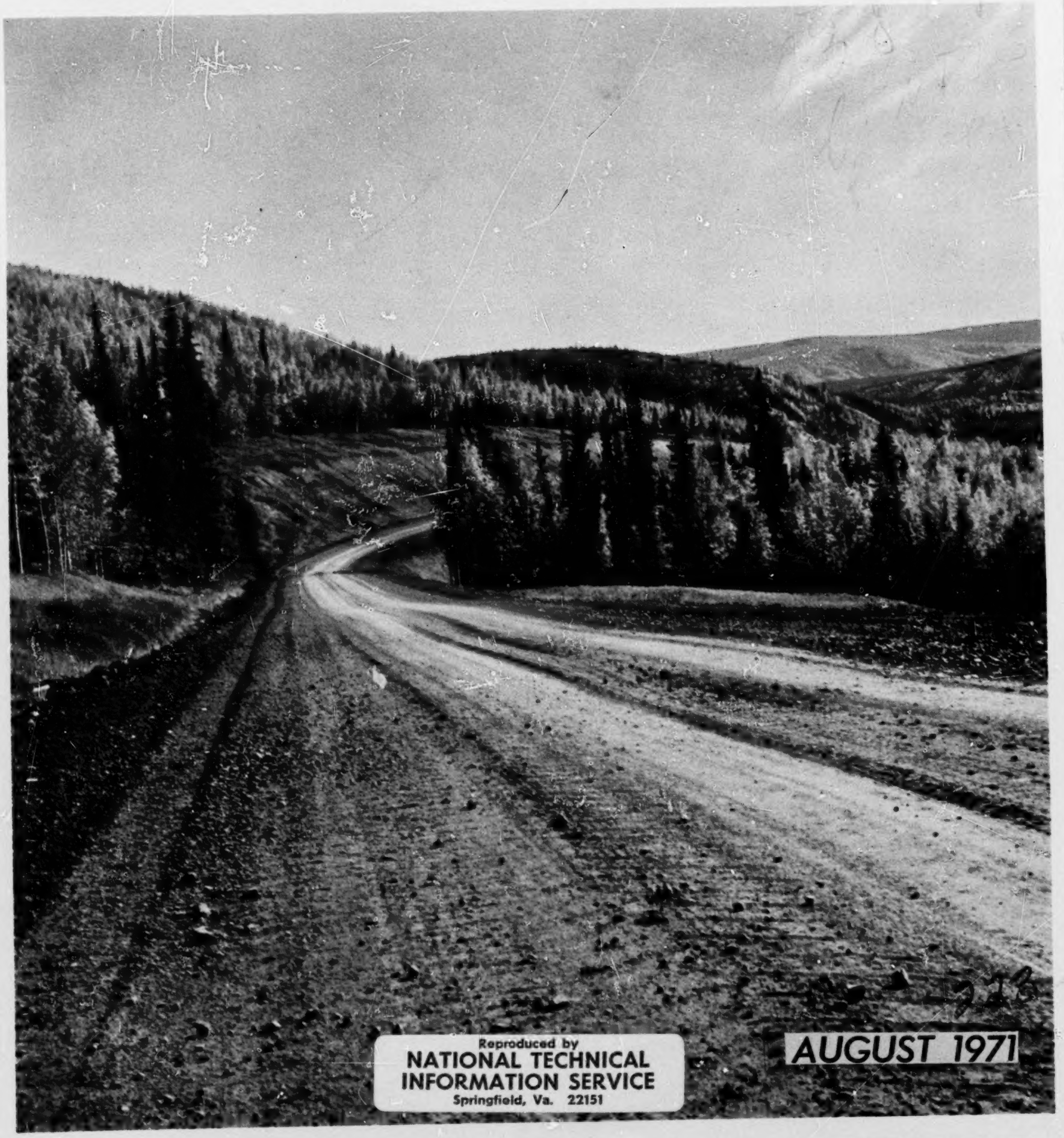
ENVIRONMENTAL GUIDELINES FOR ROAD CONSTRUCTION IN ALASKA



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16. Abstract

The purpose is to compile and describe the best practical measures required to assure environmental protection during road construction under cold climate conditions. This report summarizes accepted road construction methods for Alaska which, if followed, will help to minimize environmental degradation.

Significant conclusion include:

1. When building roads do not disturb the tundra, place gravel or other insulating material directly on undisturbed vegetation. Experience has shown that this method will minimize melting under and along the road. (Compare Figure 50 with Figures 51 and 52 with 53.)

2. Where melting has occurred do not drain away the water. Let it remain in the meltpond to freeze when cold weather returns. Because of very high ice content of tundra soils, removal of meltwater effectively causes loss of large volumes of surface soil. Subsequent seasonal melting then causes more soil removal which continues the cycle.

3. On flat tundra install sufficient drains under elevated roads to carry runoff from summer showers, otherwise this water ponds up on the upper side and can cause melting or washouts. The tundra slopes gently to the north and even small showers can result in large runoff because of the frozen subsoil and saturated soils.

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ENVIRONMENTAL GUIDELINES
FOR
ROAD CONSTRUCTION IN ALASKA

by

Frederick B. Lotspeich
Research Environmental Scientist

ENVIRONMENTAL PROTECTION AGENCY
ALASKA WATER LABORATORY
COLLEGE, ALASKA
Report No. 1610 GOI 08/71

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SECTION I

INTRODUCTION

Purpose

The purpose of this report is to compile and describe the best practical measures required to assure environmental protection during road construction under cold climate conditions. The report is intended to aid the road construction agency and highway engineer in establishing and meeting environmental protection requirements. In addition, the report will serve to inform the general public, resource managers, and equipment operators of the impact of road construction on water quality and the means available to lessen this impact.

Scope

This report summarizes accepted road construction methods for Alaska which, if followed, will help to minimize environmental degradation. No attempt will be made to probe into the engineering feasibility of various practices. It brings together the collective thinking of many Federal and State agencies whose authorized responsibility is wise management of natural resources. The intent is not to place constraints of numbers on those engaged in road construction, but to define potential pollution hazards and offer constructive suggestions for preventive measures. Design and construction engineers should be free to use alternative solutions to any problem so long as the solution meets objectives defined by resource management specialists.

Background

Figure 1 illustrates the relative size of Alaska to continental United States; the superimposed outline of Alaska covers the bulk of seven or eight north-central states with some of it extending from Georgia to California. Although Alaska's total area is 586,400 square miles, its population in 1970 was only 302,170, of which 53,000 were natives (Eskimo, Indian, and Aleut). More than half of this population occupies the metropolitan areas of two cities, Anchorage and Fairbanks. Projected population estimates to 1990 range from 339,000 to 619,000, which will still leave vast areas uninhabited. The table on page 4 summarizes major uses and ownership patterns of land and clearly indicates that the Federal Government is the dominate landowner.

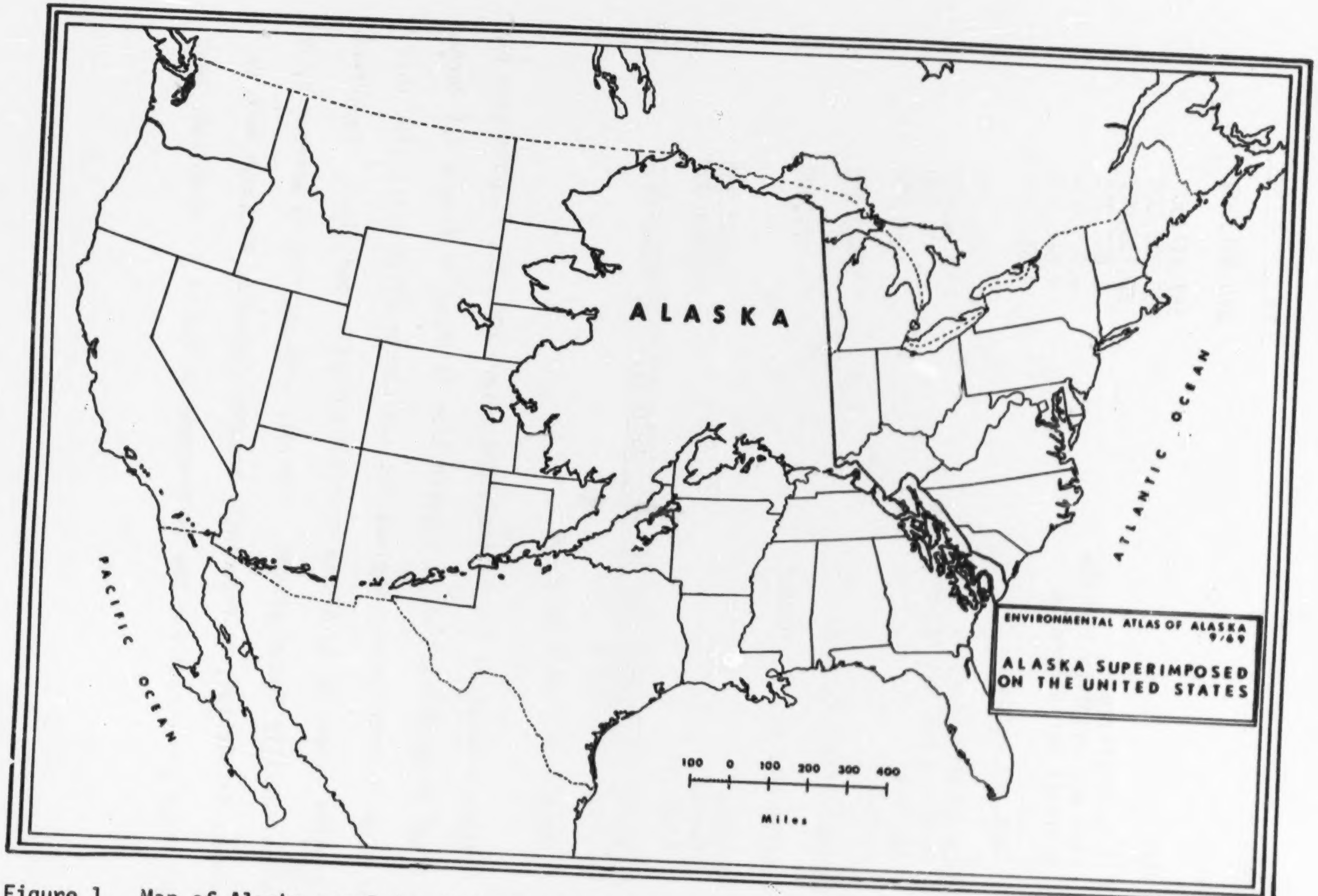
ALASKA
ENVIRONMENTAL ATLAS OF ALASKA
9/69
ALASKA SUPERIMPOSED ON THE UNITED STATES
PACIFIC OCEAN
ATLANTIC OCEAN
100 0 100 200 300 400
Miles

Figure 1. Map of Alaska overlying United States to demonstrate relative sizes--Alaska covers about seven central states (From Johnson and Hartman, 1969).

Ownership or Use	Area (in acres**)
Total	365,481,000
Federal	357,914,000
B.L.M.	305,009,000
Forest Service	20,736,000
Fish and Wildlife Service	18,632,000
National Parks Service	6,910,000
B.I.A.	4,065,000
Dept. of Defense	2,562,000
State (entitlement)	103,500,000
Selected but not approved	25,600,000
Approved	8,100,000
Boroughs	454,000
Suitable for cropland	1,640,000
Cleared but not all farmed	72,000
Forested	
Coastal	13,247,000
Interior	105,804,000

---

* From Alaska Survey and Report: 1970-71. The Research Institute of Alaska, Inc.

** Rounded off to thousands.

Alaska, because of its latitude and severe climate, is underlain by vast areas of permafrost whose distribution is shown in Figure 2. Permafrost creates problems for engineering and construction activities that add another dimension to Alaska's unique climatic conditions. Permafrost means perennially frozen ground. However, when exposed to warming by man or direct insolation, it frequently becomes unstable. Although much is known about permafrost and how to overcome or use it to advantage, each

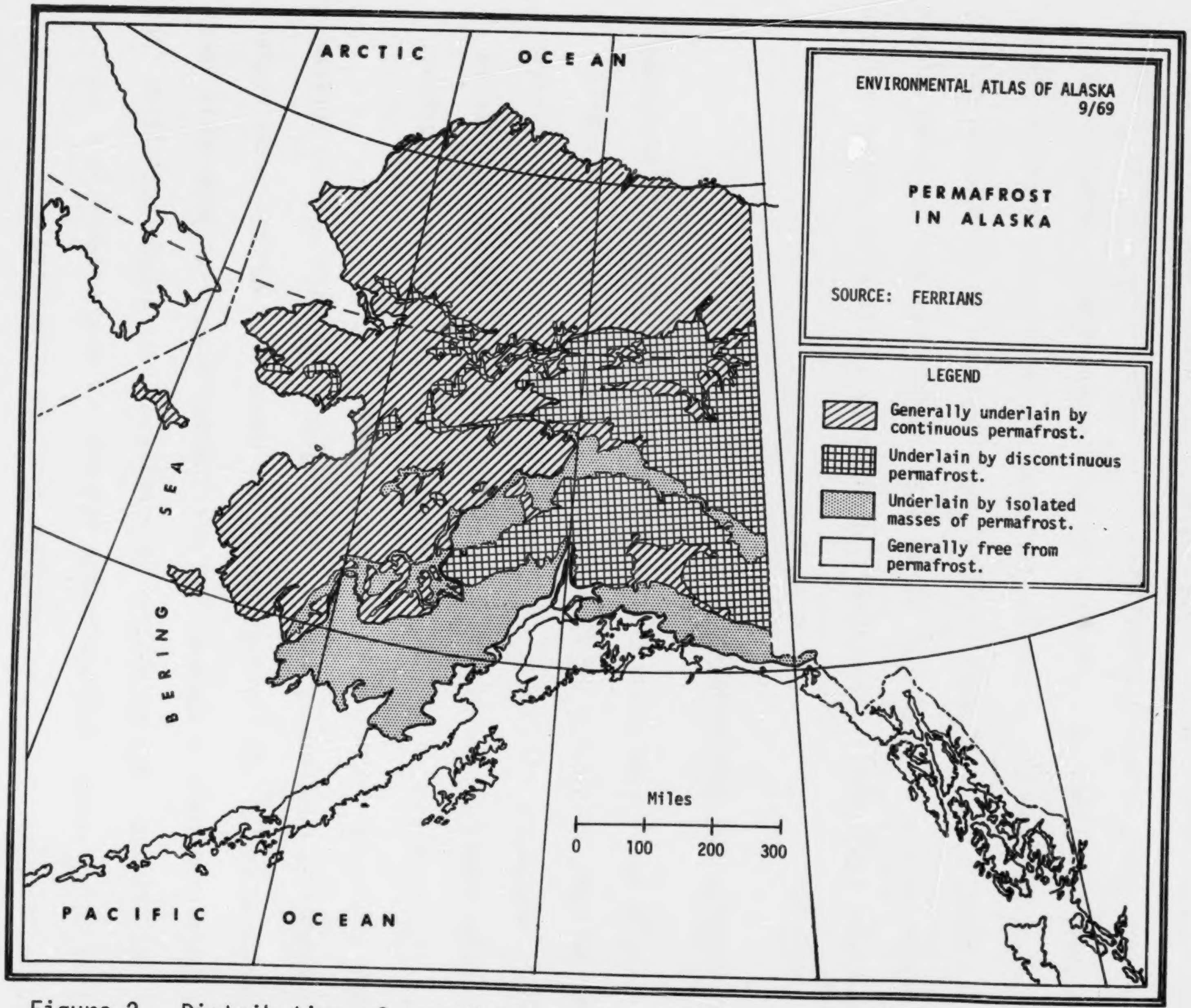
ENVIRONMENTAL ATLAS OF ALASKA
9/69
PERMAFROST
IN ALASKA
SOURCE: FERRIANS
LEGEND
▨ Generally underlain by continuous permafrost.
▦ Underlain by discontinuous permafrost.
▒ Underlain by isolated masses of permafrost.
☐ Generally free from permafrost.
ARCTIC OCEAN
BERING SEA
PACIFIC OCEAN
Miles
0
100
200
300

Figure 2. Distribution of permafrost in Alaska (From Johnson and Hartman, 1969).

project requires its own solutions. Muller (1947) cites most of the work developed in Russia through 1947 and subsequent works have appeared in proceedings of various permafrost conferences (International Permafrost Conference, 1963; Canadian conferences in 1967 and 1969). Philleo (1963) gives some guidelines to overcome problems associated with permafrost and cites examples from his personal experience. A recent book by Brown (1970) gives a good, up-to-date discussion of permafrost and is recommended reading for anyone who is involved with permafrost. Guidelines developed for Alaska should have applicability to Canada, or other countries with similar climate and permafrost.

Road Construction Considerations

Alaska has a wide range of topographic features (Figure 3) including broad valleys, undulating uplands, fjords, rugged mountains, and coastal plains. Distances are great, as illustrated in Figure 4, and roads generally nonexistant except for the limited road-net shown as solid lines in Figure 5. Most travel to outlying points is by some kind of air service; either commercial, charter, or privately owned.

Alaska is essentially a wilderness region which will require surface transportation for orderly development and commerce. Surface water routes have been important in the past but are limited because of geographic location and climate. New technology is permitting year-around activities that utilize an all-season transportation network. A road network is a logical solution to many of the transportation problems associated with resource development and commerce due to all-season use, shorter distances, and direct

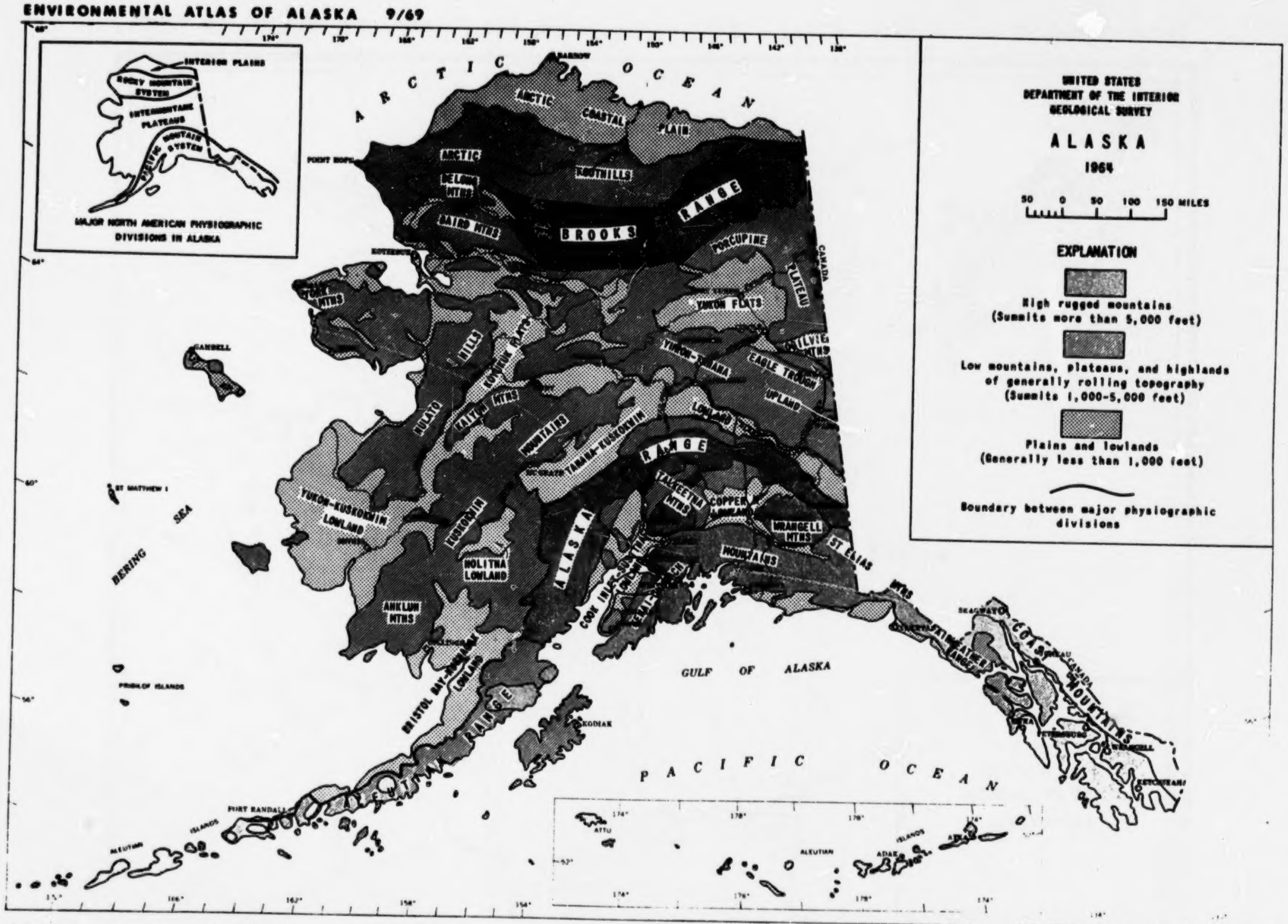
ENVIRONMENTAL ATLAS OF ALASKA 9/69
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
ALASKA
1964
50 0 50 100 150 MILES
EXPLANATION
High rugged mountains (Summits more than 5,000 feet)
Low mountains, plateaus, and highlands of generally rolling topography (Summits 1,000-5,000 feet)
Plains and lowlands (Generally less than 1,000 feet)
Boundary between major physiographic divisions
INTERIOR PLAINS
ROCKY MOUNTAIN SYSTEM
INTERMONTANE PLATEAUS
PACIFIC MOUNTAIN SYSTEM
MAJOR NORTH AMERICAN PHYSIOGRAPHIC DIVISIONS IN ALASKA
ARCTIC OCEAN
ARCTIC COASTAL PLAIN
FOOTHILLS
BROOKS RANGE
DeLONG MTNS
BAIRD MTNS
PORCUPINE
PLATEAU
YUKON FLATS
EAGLE TROUGH
UPLAND
LOWLAND
ALASKA RANGE
TALKEETNA MTNS
COPPER
WRANGELL MTNS
ST ELIAS MTNS
MOUNTAINS
COOK INLET
KUSKOKWIM MTNS
NULATO
YUKON-KUSKOKWIM LOWLAND
HOLITNA LOWLAND
AHKLUN MTNS
BRISTOL BAY LOWLAND
ALEUTIAN RANGE
COAST MOUNTAINS
CANADA
BERING SEA
ST MATTHEW I
PRIBILOF ISLANDS
GAMBELL
KODIAK
GULF OF ALASKA
PACIFIC OCEAN
ALEUTIAN ISLANDS
PORT RANDALL
ATTU
ADAK
SKAGWAY
KETCHIKAN
POINT HOPE
BARROW
KOTZEBUE

Figure 3. Physiograph provinces of Alaska. (From Johnson and Hartman, 1969)

After Clyde Wahrhaftig

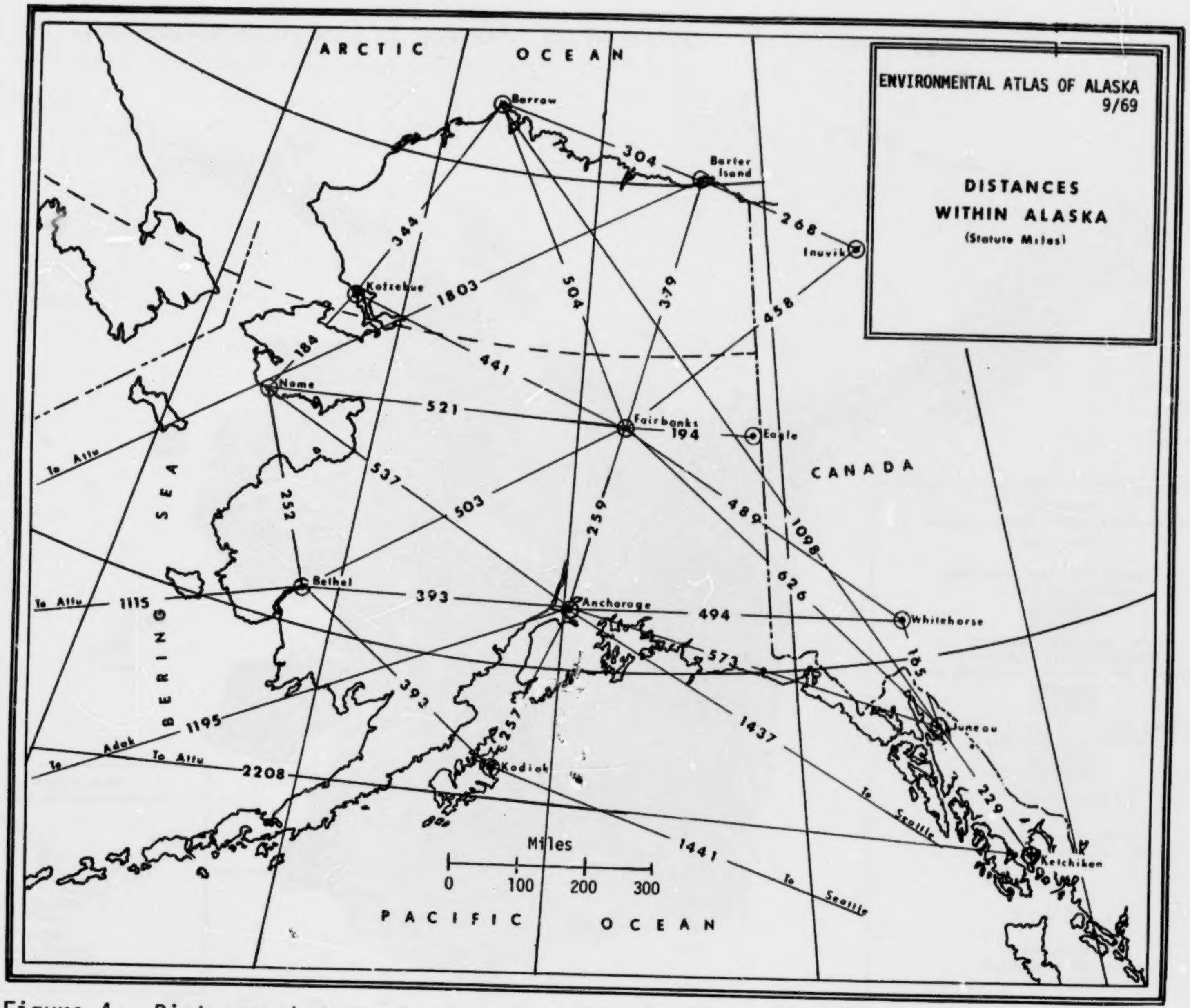
ENVIRONMENTAL ATLAS OF ALASKA
9/69
DISTANCES
WITHIN ALASKA
(Statute Miles)
ARCTIC
OCEAN
BERING
SEA
PACIFIC
OCEAN
CANADA
Barrow
Barter Island
Inuvik
Kotzebue
Nome
Fairbanks
Eagle
Bethel
Anchorage
Whitehorse
Juneau
Kodiak
Ketchikan
304
268
344
1803
504
379
458
184
441
521
194
537
503
252
259
489
1098
626
393
494
1115
573
165
393
257
1195
1437
2208
229
1441
To Attu
To Attu
To Adak
To Attu
To Seattle
To Seattle
Miles
0
100
200
300

Figure 4. Distances between key points in Alaska. (From Johnson and Hartman, 1969)

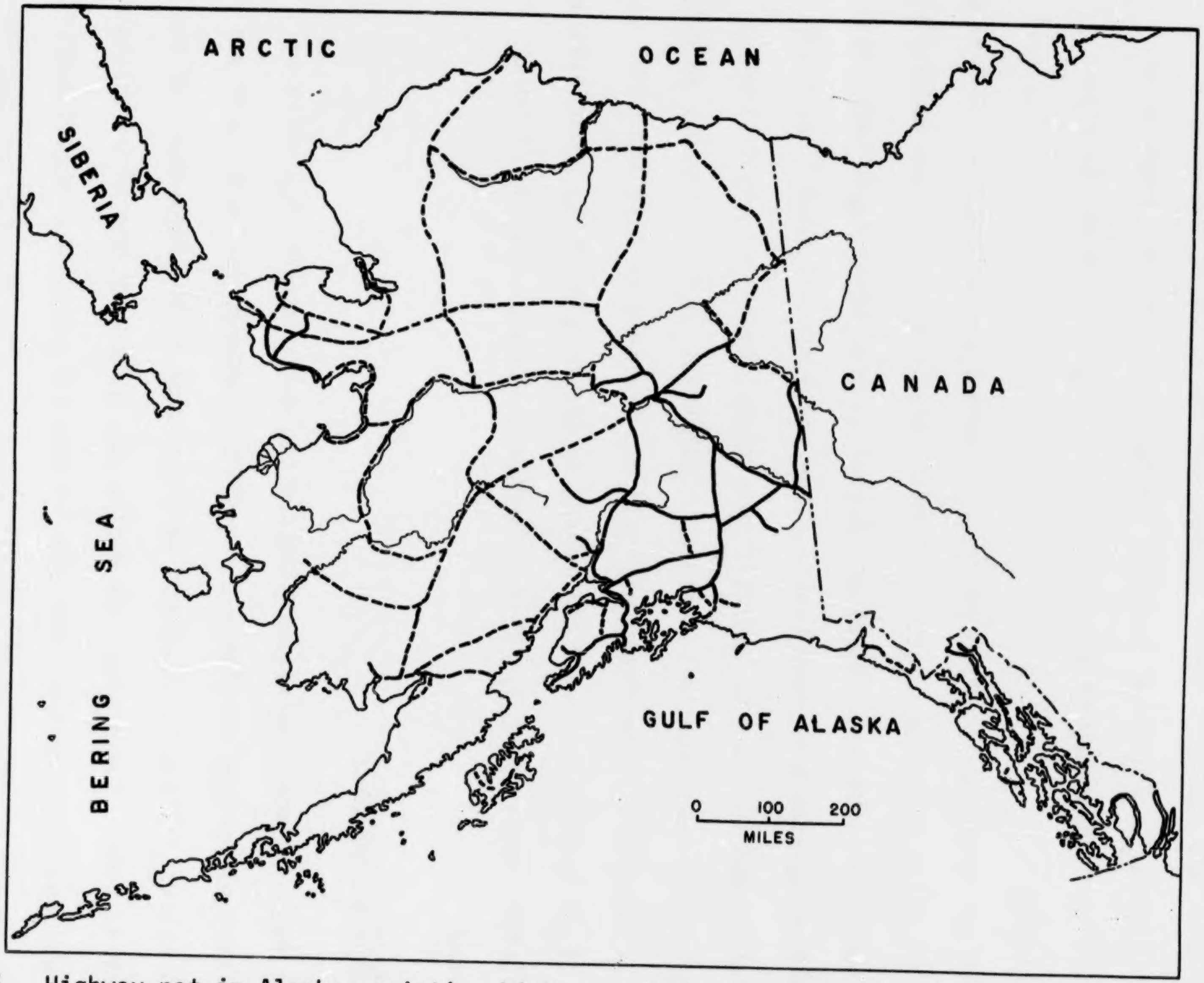
ARCTIC
OCEAN
SIBERIA
CANADA
BERING SEA
GULF OF ALASKA
0
100
200
MILES

Figure 5. Highway net in Alaska--existing highways, both paved and gravel; 3550 miles are solid lines; proposed long-range construction 8580 miles, are shown as dashed lines (From State of Alaska Department of Highways map, September 1970).

access to areas of development. Thus the likelihood of additional highway construction becomes more certain. The State has developed a long-range program (20 years) to build several hundred miles of new roads as shown in Figure 5. This plan includes the haul road for the proposed oil pipeline from Prudhoe Bay on the Arctic Ocean to Valdez Harbor in Prince William Sound.

Road construction, without forethought toward preserving environmental quality of other resources--water, wildlife, fish, recreation and aesthetics --can lead to serious and unnecessary degradation of these resources. Waste materials associated with road construction are a form of industrial waste and usually take the form of sediment in streams, debris on right-of-ways, and unnecessary scars on the landscape. Sedimentation has a serious adverse effect on aquatic life and some materials may be toxic to fish and other stream life. It is relatively simple to prevent damage to streams by sedimentation; the principal requirement is the realization that water quality is worth preserving.

Water Quality Standards

In 1965, Congress unanimously passed the Water Quality Act which required that all states develop water quality standards for interstate and coastal waters. Alaska's standards were approved by the Department of the Interior in 1968. These standards define the concentrations of polluting substances permitted in the water and include all substances that interfere with the normal functioning of natural waters as a resource to be used for man's benefit. Silt and other products of erosion that enter waters are included in these standards. Although levels of polluting substances are set by these standards, provision is made for revision and updating as new knowledge or requirements make it necessary. It is these standards that form the basis for the development of guidelines to assist industry in meeting the requirements of the new National Environmental Policy Act (P.L. 91190).

National Environmental Policy Act

Public sentiment is building for renewed effort to preserve our environment. An awareness has developed that, unless we do, our present way of life is in jeopardy. Such sentiment is reflected by Congress, who, late in 1969, enacted a law describing a national policy for the environment (Public Law 91190, National Environmental Policy Act) and provided the President with a permanent Council on Environmental Quality. This law is now the law of the land and all Federal, State, and local organizations are required to abide by provisions contained in the Act. As stated in Section 2 of the Act, its purposes are:

> "SEC. 2. The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality."

Under

> "SEC. 101. (a) The Congress...declares that it is the continuing policy of the Federal Government, in cooperation with State and local governments, and other concerned public and private organizations to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in

> productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans."

Subsequent sections describe in detail measures written into the Act to implement and achieve its stated purpose. All persons responsible for activities likely to have an environmental impact should become intimately acquainted with its intent and provisions.

In response to this Act and related Executive Order, the Bureau of Public Roads issued a series of instructional memorandums dealing with specific pollutants associated with road building. Copies of the Act, Executive Order, and Instructions are included as an appendix.

SECTION II

ROUTE SELECTION

Route selection is the first field activity in road construction. McHarg (1969) offers some refreshing suggestions on selecting routes and alternatives to the conventional approach. He attempts to make use of the total ecology of the region through which the road will pass, in addition to the usual engineering criteria. When total social costs, including damage to other resources, are balanced against benefits for alternate routes, an alternate longer route frequently offers the best solution. Long-range costs must be in balance with short- and long- range benefits.

In reality, route selection should start by map reconnaissance. Topographic and aerial maps are extensively used in selecting tentative routes but field experience is helpful to the initial study. In Alaska, route selection to take advantage of non-permafrost terrain or avoid obvious patterned ground is extremely important. Permafrost adds another dimension to route selection in addition to those needing attention in more temperate regions. (Figures 6 - 8 illustrate some problems associated with this stage of construction in Alaska.)

South slopes may be free of frost, especially near ridge lines, and poorly drained low ground is usually underlain by frost. Aerial photos are valuable aids in these early stages of route selection because patterned ground as an indicator of ice is easily seen and avoided. Vegetation can be used by an experienced interpreter to indicate drainage

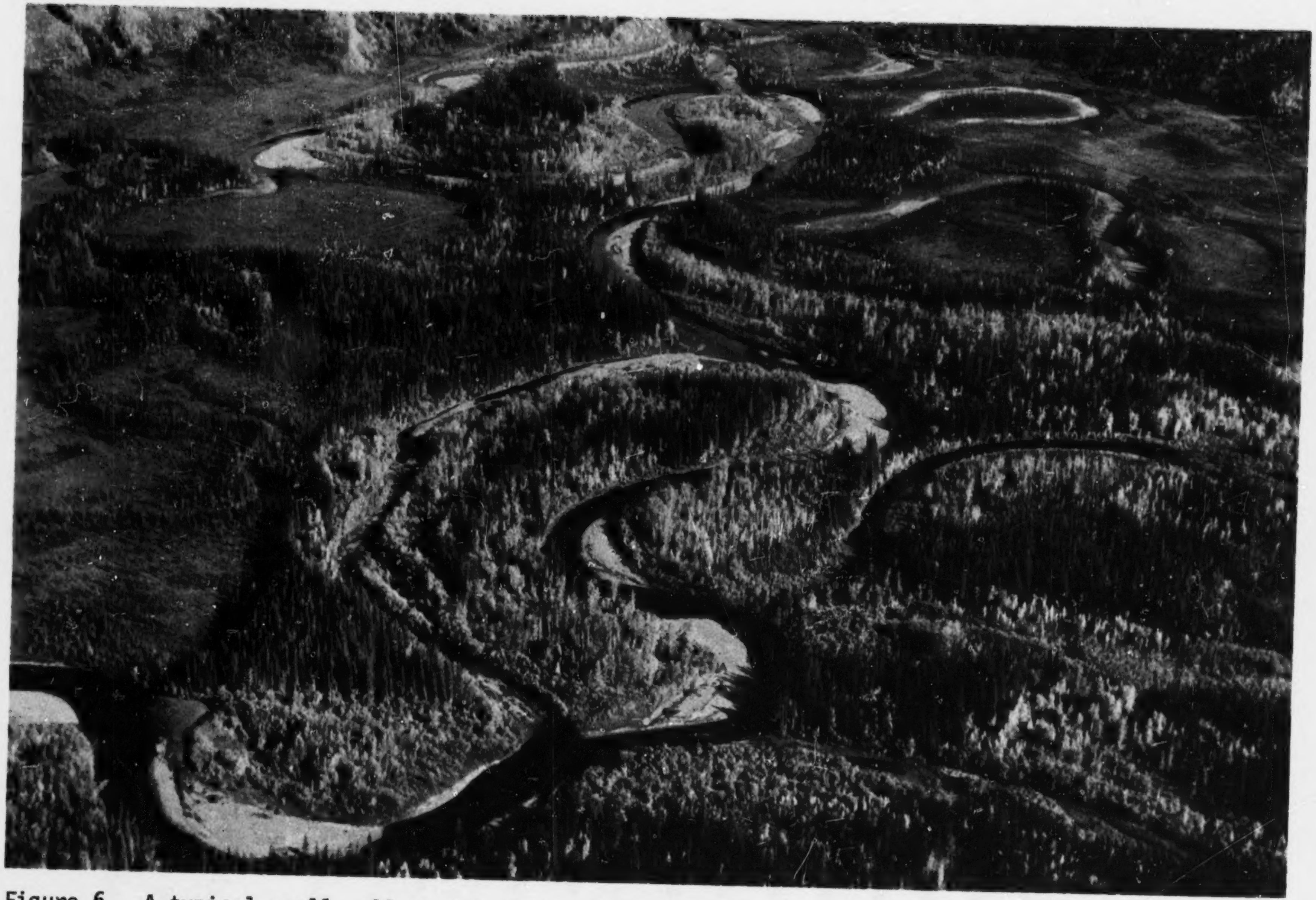

Figure 6. A typical small valley of interior Alaska that illustrates the problem of route selection; this stream must be crossed but where and how.

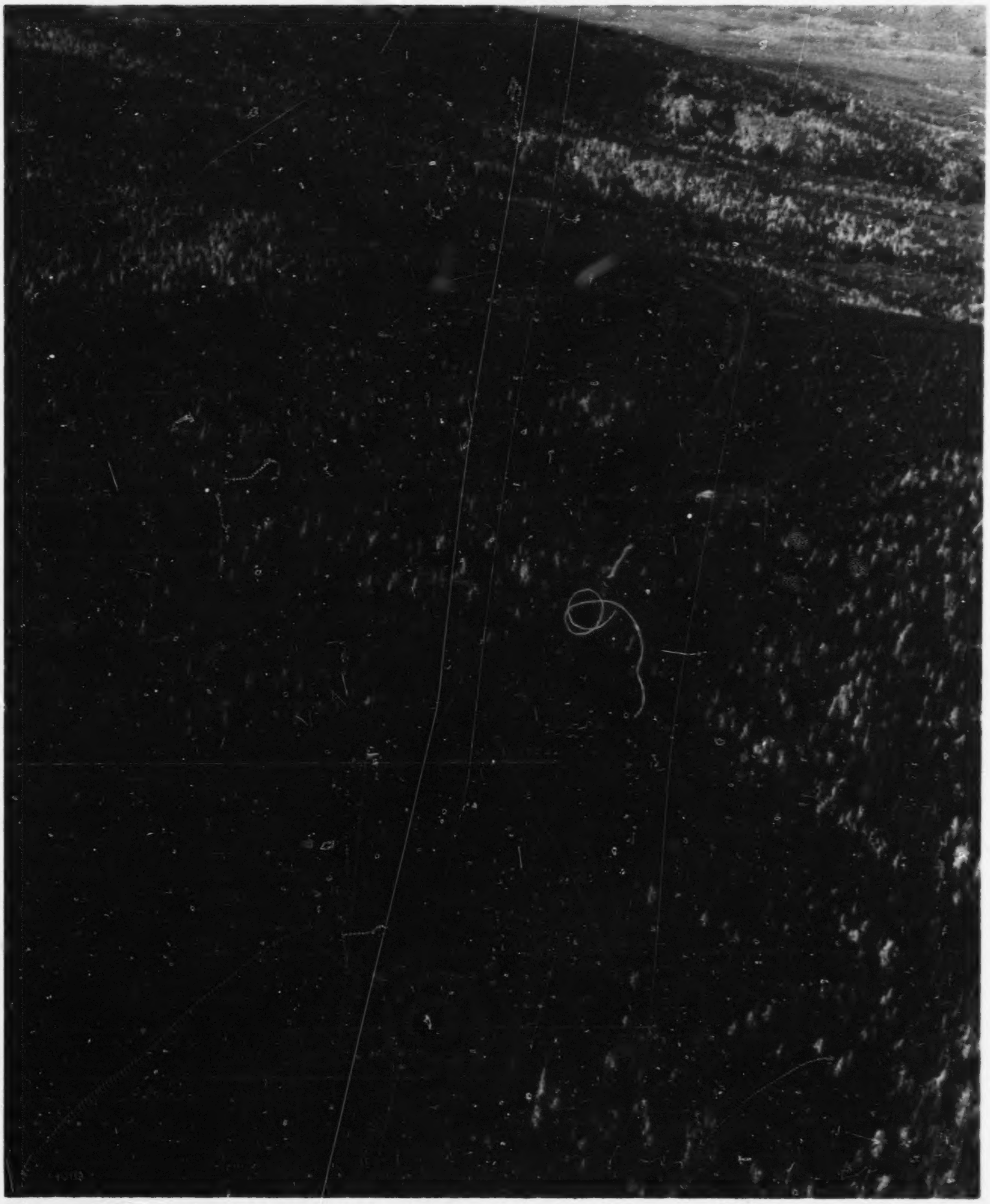

Figure 7. Centerline marked with bulldozer after route is selected and surveyed. Much of centerline clearing is done by hand which costs more but does less damage to the vegetal mat which needs to be preserved. Typical terrain and forests of interior Alaska; note the heliport. A large portion of total traveling during these early phases is by helicopter.

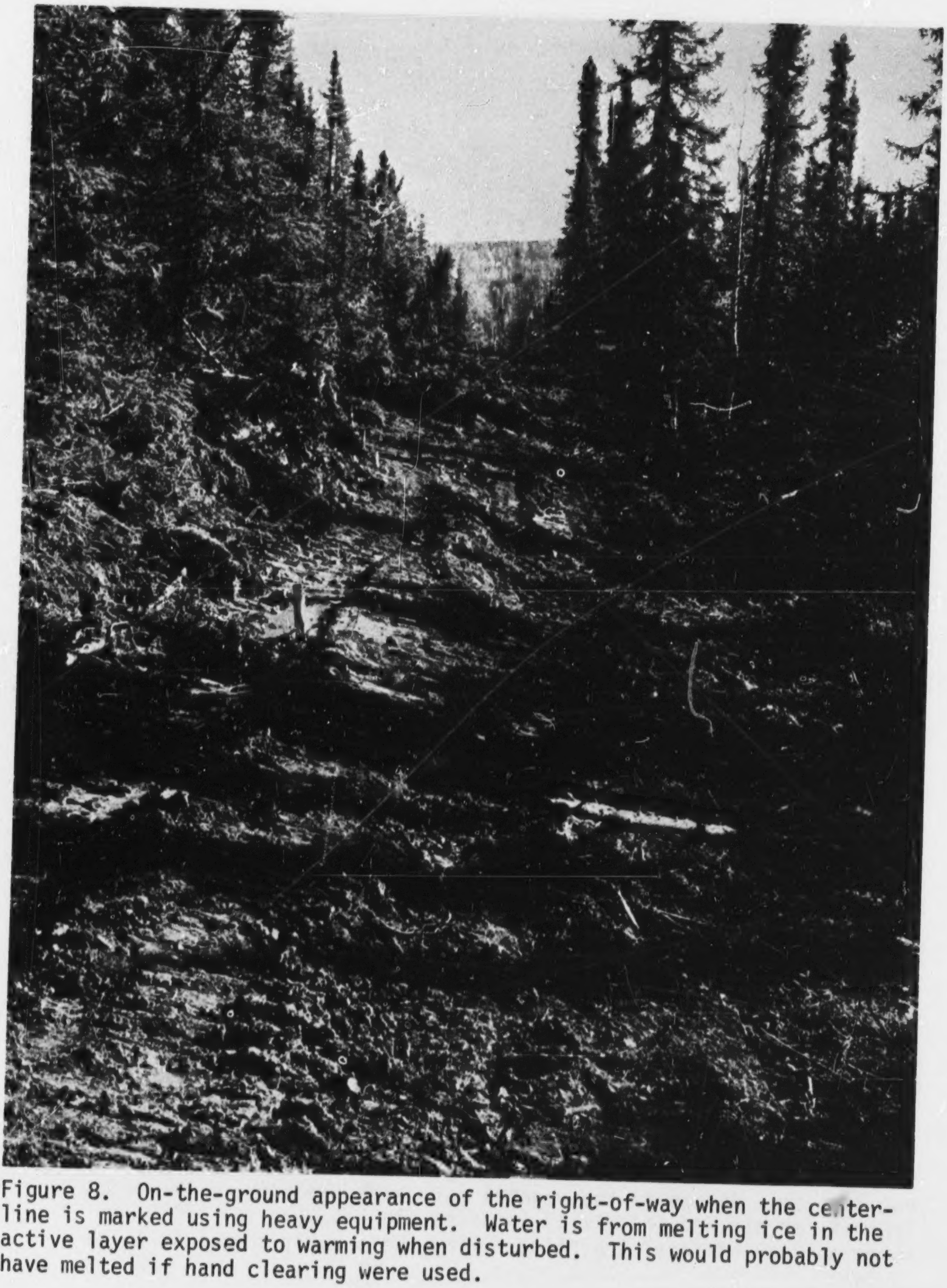

Figure 8. On-the-ground appearance of the right-of-way when the centerline is marked using heavy equipment. Water is from melting ice in the active layer exposed to warming when disturbed. This would probably not have melted if hand clearing were used.

conditions, and with caution, gain some insight into general soil textures. No form of remote sensing, however, can pick up permafrost or ice masses in unpatterned terrain and gaurantee that a selected route will be free of ice.

Although obvious high-ice areas can be avoided during map reconnaissance nearly every valley that must be crossed is a potential problem area. Final selection of a route must be done on the ground and numerous borings made to examine subsurface soil materials. It is this stage that must be intensive, because, if trouble spots are not detected early, costs can rise far above expectations. Money spent on route selection is money wisely invested. As an example, the road from Livengood to the Yukon was estimated to cost 10 million dollars; because of unforeseen difficulties that should have come to light by intensive reconnaissance, it has exceeded that estimate by 50-100 percent.

Route selection should consider other resources, e.g., water, recreation, minerals and timber. Planning the route with these in mind will minimize damage and keep costs down.

Guidelines for Route Selection:

1. Make an intensive map reconnaissance to achieve maximum use of topography and avoid areas of obvious high ice content. Do not rely on photos to detect all frozen soils.

2. Fully consider other resources and future land management problems along the route. Attempt to complete all exploration when the ground is frozen to avoid damage by cross-country vehicles.

3. When conducting soils investigations, bore enough exploratory holes to definitely establish the location of massive ice as well as construction materials. If ice cannot be avoided, the design engineer will at least be able to consider its presence during design.

4. Avoid seepage zones by routing high on slopes where possible.

5. If valleys must be followed, locate the route on terraces; these are usually better drained and are above normal flood levels.

6. In crossing streams, approach banks at right angles to avoid unnecessary fills in the active channel.

SECTION III

ENGINEERING DESIGN

Once the final route is selected, and the materials available become known, the design engineer, in consultation with his geologist and materials specialists, can start active design work. If the reconnaissance has been sufficiently intensive, there should be no surprises and all problem areas will be accounted for during design. Although cut and fill balancing is preferred where feasible, permafrost may dictate placing overlay directly on the undisturbed moss layer. Overlay of sufficient depth to prevent or retard melting requires greater volumes of fill material than conventional cut and fill. Design engineers familiar with the many forms of permafrost assert that in areas of discontinuous or sporadic permafrost, no cost-justified quantity of fill will prevent melting, although such fill will retard and thus help control melting. However, where continuous permafrost is present, with its colder temperature and shorter melt season, a reasonable depth of overlay will maintain the frozen soil intact.

With the new mandate to minimize damage to other resources during industrial development, it becomes desirable to include specialists in renewable resource management on the design teams as well as in route selection. These specialists would work directly with engineers to develop solutions to potential problems that meet both engineering and environmental requirements. By designing solutions early in the complete project, delays and unsound procedures can be avoided, resulting in superior engineering works without endangering environmental values.

The demand for larger volumes of fill material, and the constraint that other resources be part of the overall plan, places severe restrictions on siting borrow areas. Normally, borrow pits are sited for the convenience of the user but as other resources enter into the design, they may have to be spaced farther apart, resulting in longer hauls. Although longer hauls result in higher costs, these costs must be balanced against the value of other resources associated with the route. Such evaluation poses problems because some resources defy outright dollar value; i.e., esthetics and recreation. Uses for borrow areas, after completion of the project, should enter into the design and be planned into the actual construction operations.

Sufficient cross-drainage structures between natural drainages must be provided because intermittent freezing can cause damage to a road as ice builds up behind the fill and overflows during melting. Streams that are actually cutting their banks should be bridged if trees and other tall vegetation grow on their watersheds. During "breakup", trees and other debris are carried downstream and can clog culverts if these are used as stream crossings. Bridges should be sited in a manner that will least affect the normal stream hydraulics. Once a stable stream is altered, other unexpected effects follow, sometimes with dire results and always with increased maintenance costs. Engineers and geologists with design experience in permafrost areas of Alaska are confident that they can design a road when they know in advance the nature and extent of permafrost. In areas of silty soils with large ice masses, sufficient thickness of overlay fill material must be utilized to retard melting of ice and promote road bed stability. Where dry silty soils prevail, conventional cut and fill methods may be used. Where the route traverses coarse subsoil materials, even where these are frozen, a stable road can be built without the large volumes of fill material. An experienced materials specialist can quickly evaluate different materials as to their bearing capacity, stability when thawed, and other engineering properties. Each change in subsoil material, drainage conditions, and extent of ice poses an individual problem to be solved in advance of construction if at all possible.

Seepage areas that cannot be avoided during route selection must be accounted for in design and planning for maintenance. Seeps on a road may build up to large ice masses during the long winters in Alaska and constitute a serious driving hazard. "French drains" are one suggested means of coping with small seeps (see Navdocks, 1955). Culverts tend to fill with ice unless some heat is provided to keep a small channel open. Hessian cloth fence is another means of controlling "icings" as these ice masses are called.

Good design, even when seepage is a problem, can prevent the development of "frost boils" with their attendant maintenance problems. A well-drained subgrade of coarse gravel will prevent water from accumulating under the finished surface, thereby eliminating a cause of frost boils. If materials are economically available, there is no reason why any new road should have these failures. Maintenance costs, loss in time, and weight restrictions over a few years far outweigh the added costs of more distant materials, added engineering, and deliberate construction techniques.

Even where maximum care is exercised in selecting a route by using high ground, some valleys must inevitably be crossed. The road must consequently descend from the ridge tops dictating extensive cutting and filling. Some of these cut zones may have large percentages of ice and cannot be used as fill but must be wasted. This high-ice material is usually silt that will cause pollution problems as the excavated material melts. Two procedures for minimizing the environmental impact of these waste materials are being tried on the Livengood-Yukon road: (1) Cuts are made vertical and thus reduce the total volume of ice removed; and (2) The waste piled as deep and compact as possible for minimum exposed surface. Waste areas should be covered by some material to prevent wind or water erosion. An opportunity to observe vertical cuts of ice and silt was offered on the new section of road mentioned earlier. It was observed on April 30, 1970, that one cut receiving insolation was melting, whereas, the cut opposite showed no evidence of melting.

Transition from cuts that are dominantly ice to fill which is rock creates an unstable point at the interface of the unlike materials which is likely to cause pollution problems. One observation made by a Bureau of Land Management inspector in such a case was that the portion exposed to melting should have an insulating blanket of fill material placed on the frozen surface as soon as the cut was down to grade. Special attention should be given to such an interface to prevent thawed silt from entering any small stream being crossed by the road. (Figures 9 - 17 illustrate some of the problems of designing for permafrost.)

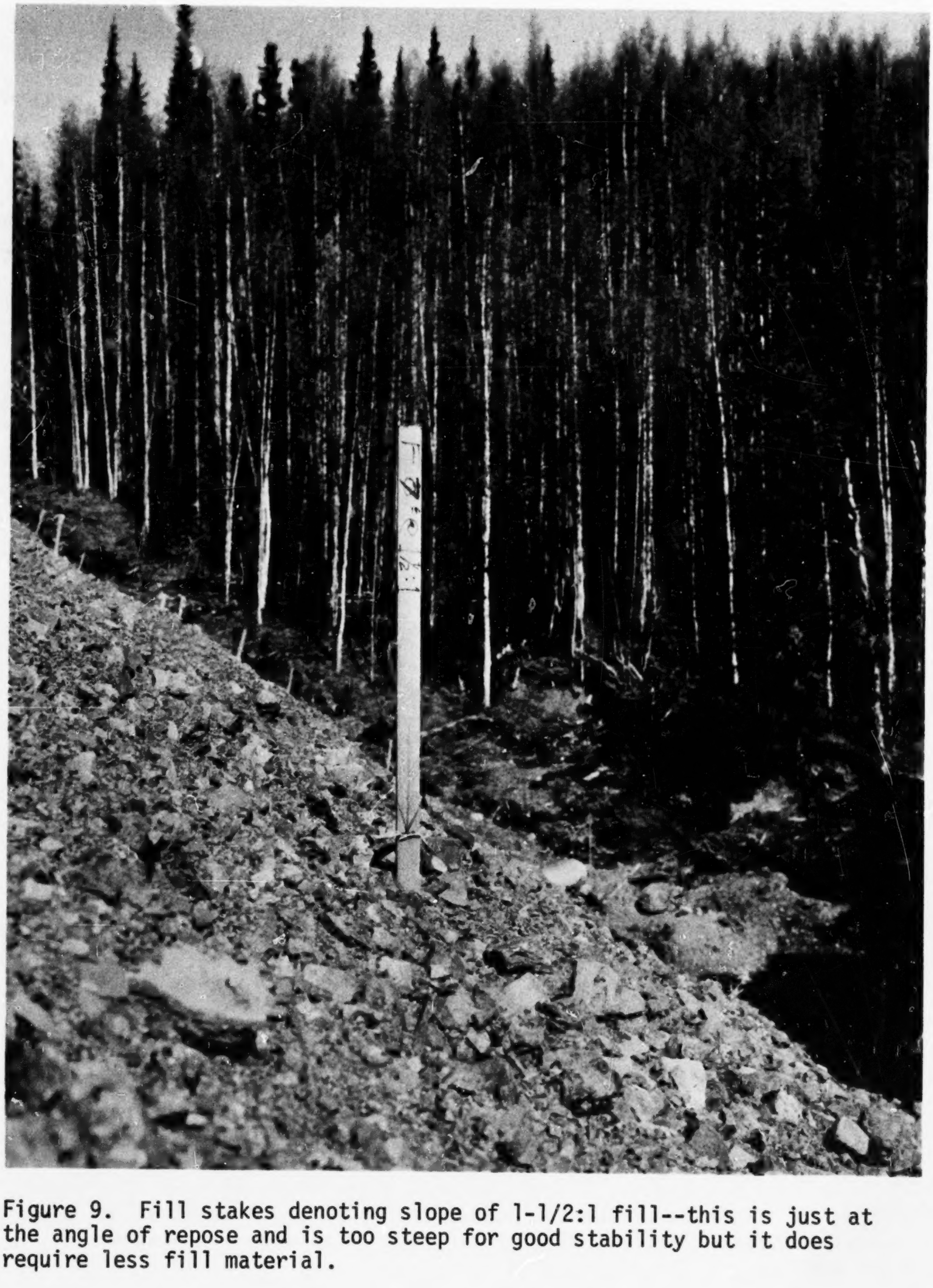

Figure 9. Fill stakes denoting slope of 1-1/2:1 fill--this is just at the angle of repose and is too steep for good stability but it does require less fill material.

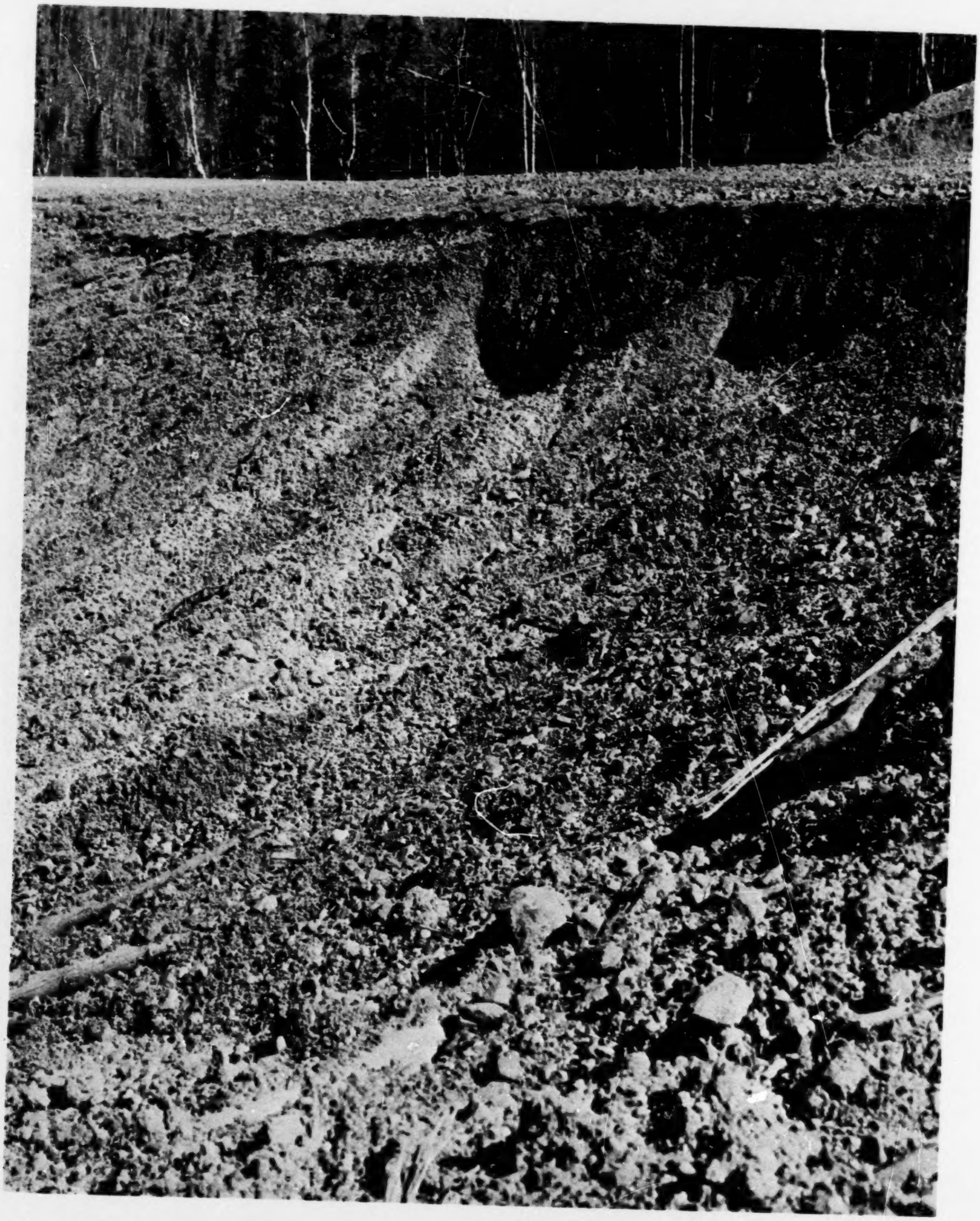

Figure 10. Failure of the fill shown in Figure 9. A small slide is shown which is enlarging, illustrating the oversteep fill because of poor design.

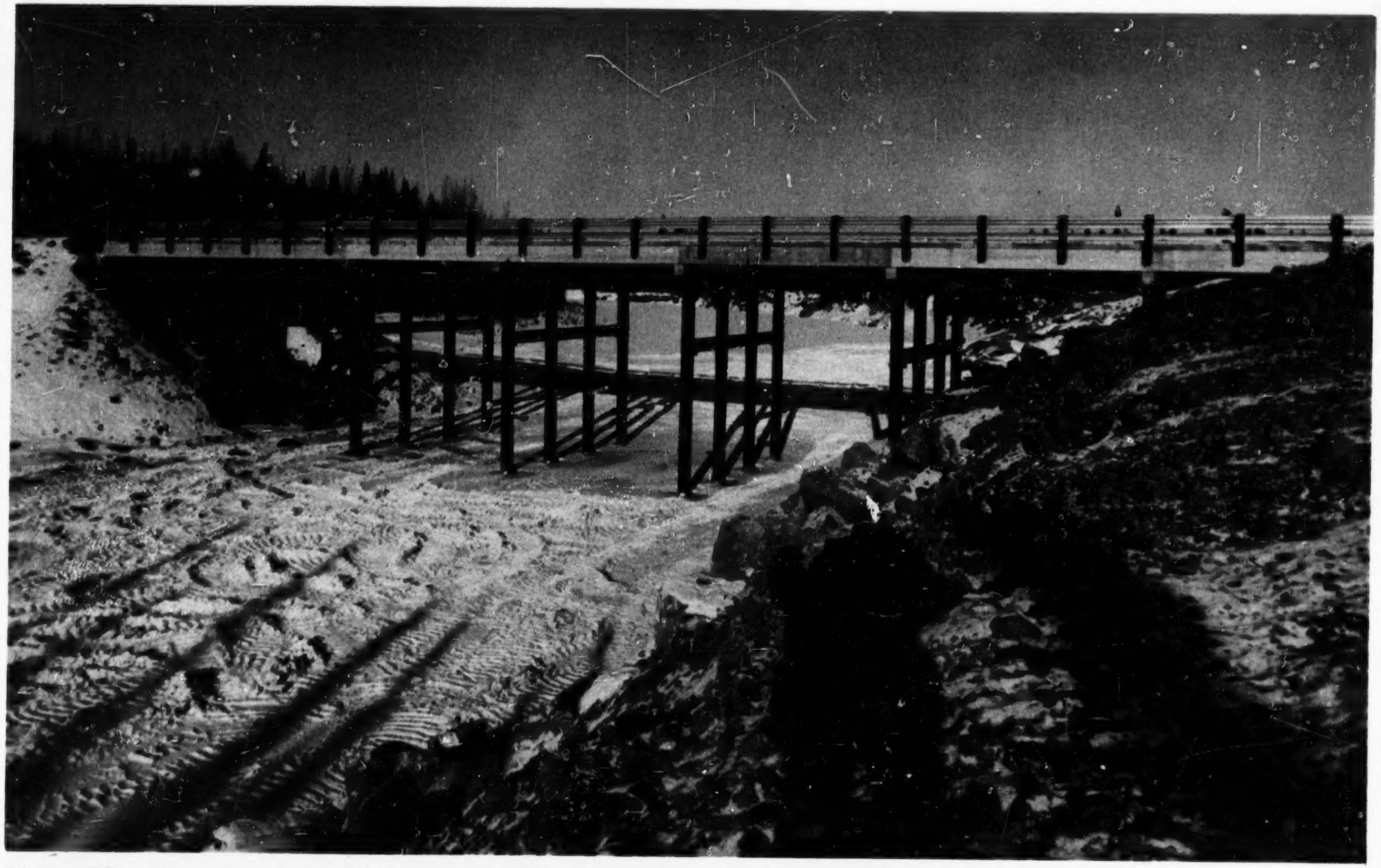

Figure 11. Example of a bridge design that is not recommended by Alaska Department of Highways. Although it has ample strength and is properly installed, the spans are too short and tend to clog with logs, trees, and other debris during breakup or other times of high water. Many white spruce in these valleys are about 100 feet tall and can easily span several pilings of such a bridge. Constant vigilance is necessary during high water to prevent a jam which could cause a washout.

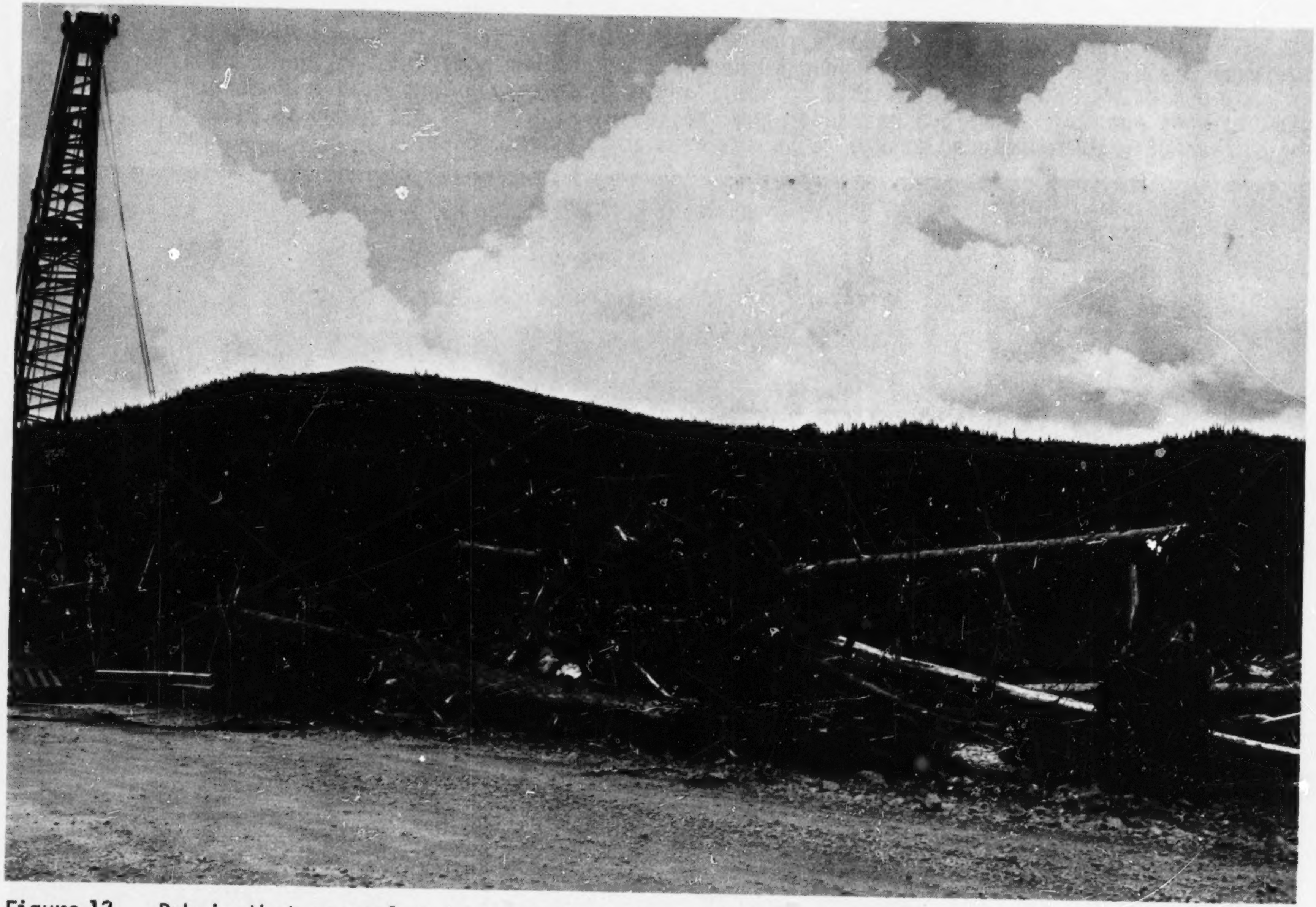

Figure 12. Debris that accumulated behind the bridge shown in Figure 11. This debris resulted from moderate rains; timely removal by the clamshell prevented possible damage. July 2, 1970.

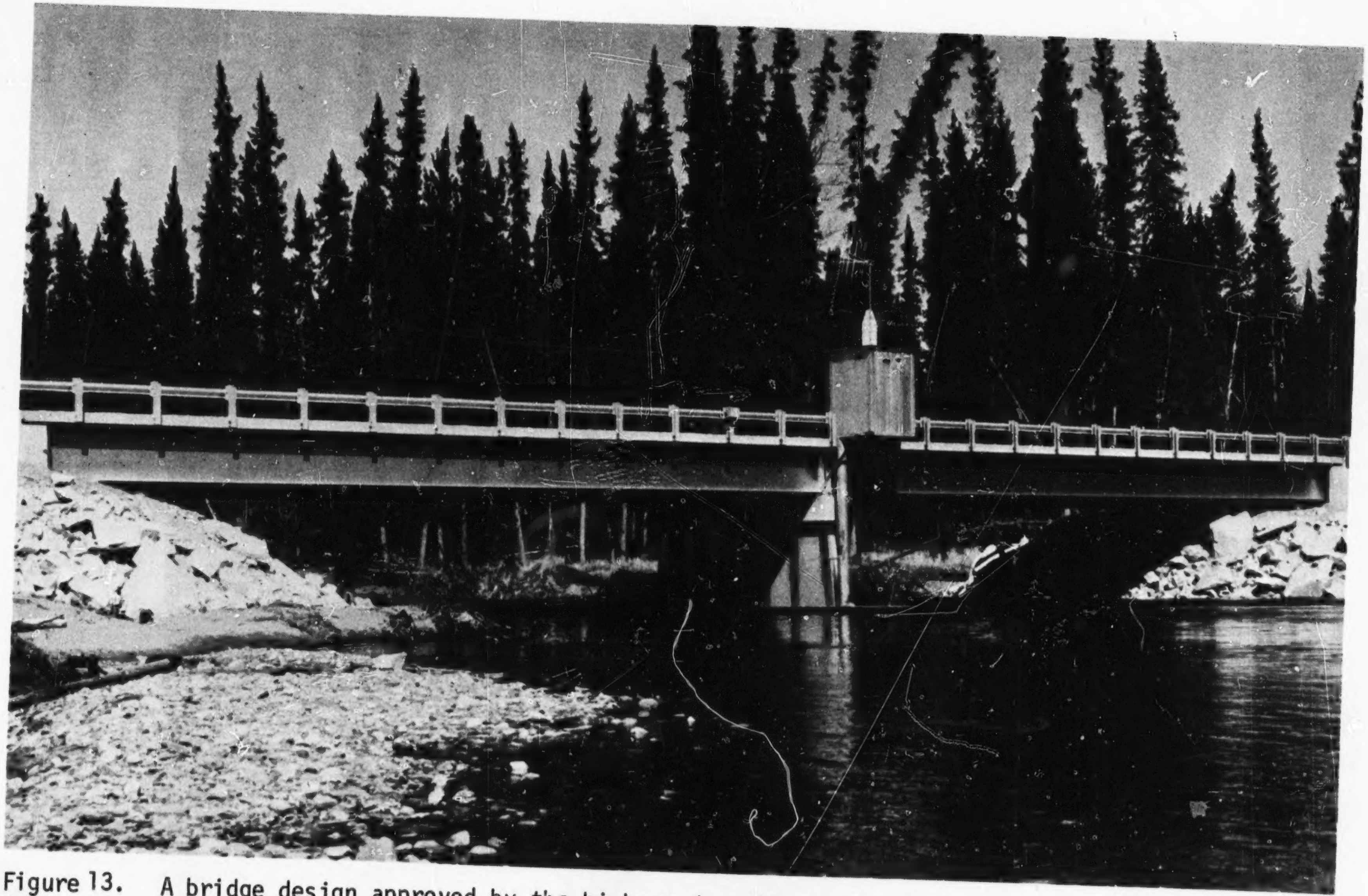

Figure 13. A bridge design approved by the highway department. Note the long spans, each about 80 feet, the single pier and lack of any restriction or alteration of river hydraulics. Trees in the background are 100 foot white spruce. Even with these spans, debris collects on the pier but most of the logs and trees pass on unless they center on the single pier. (Chena Hot Springs Road)

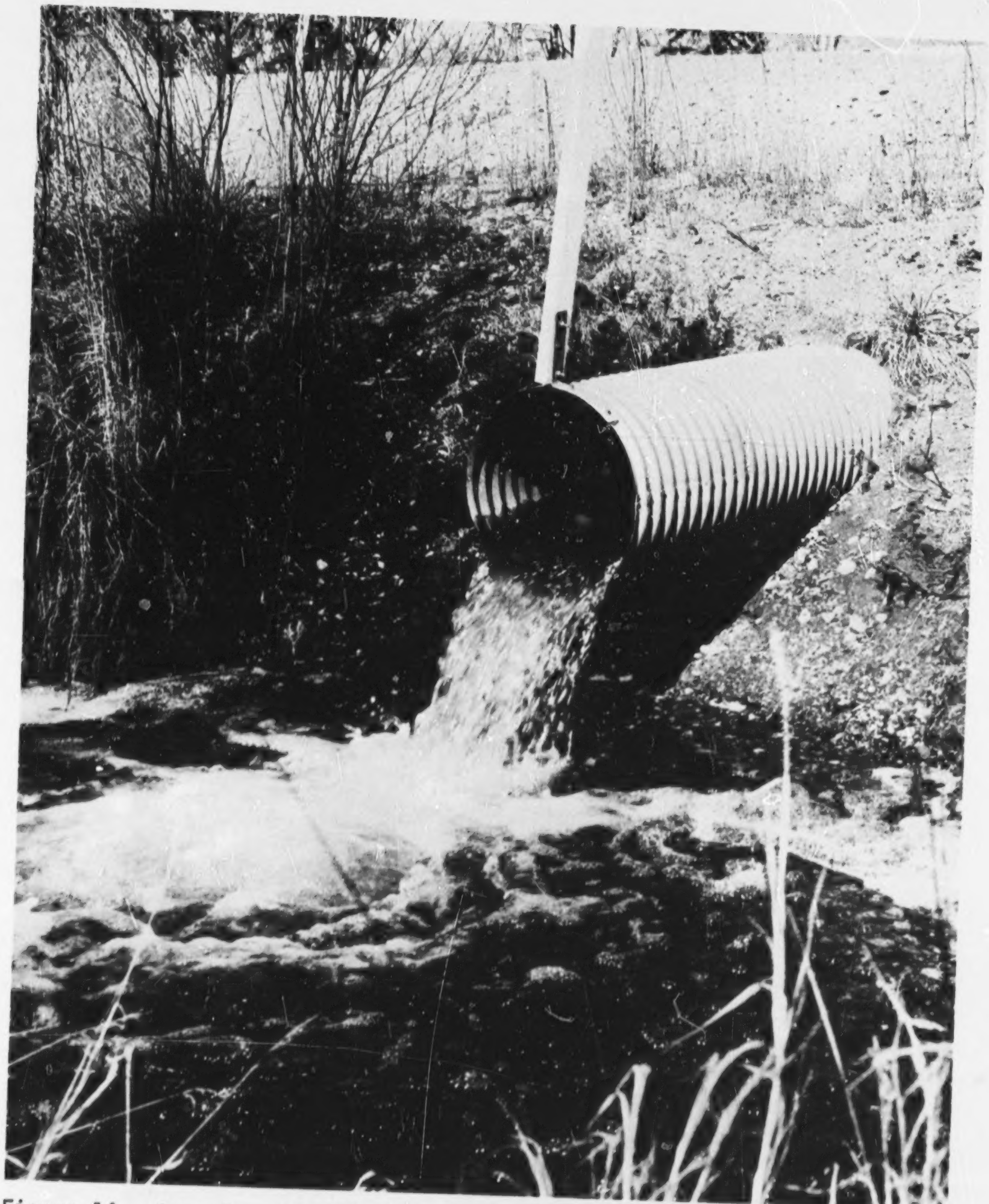

Figure 14. Example of an improperly designed and installed culvert for perennial streams. Grayling spawn in these small streams and such an installation acts as a dam and prevents them from reaching the headwaters. In 1967, many grayling were observed in the small plunge pool shown here but they could not proceed further because of the culvert.

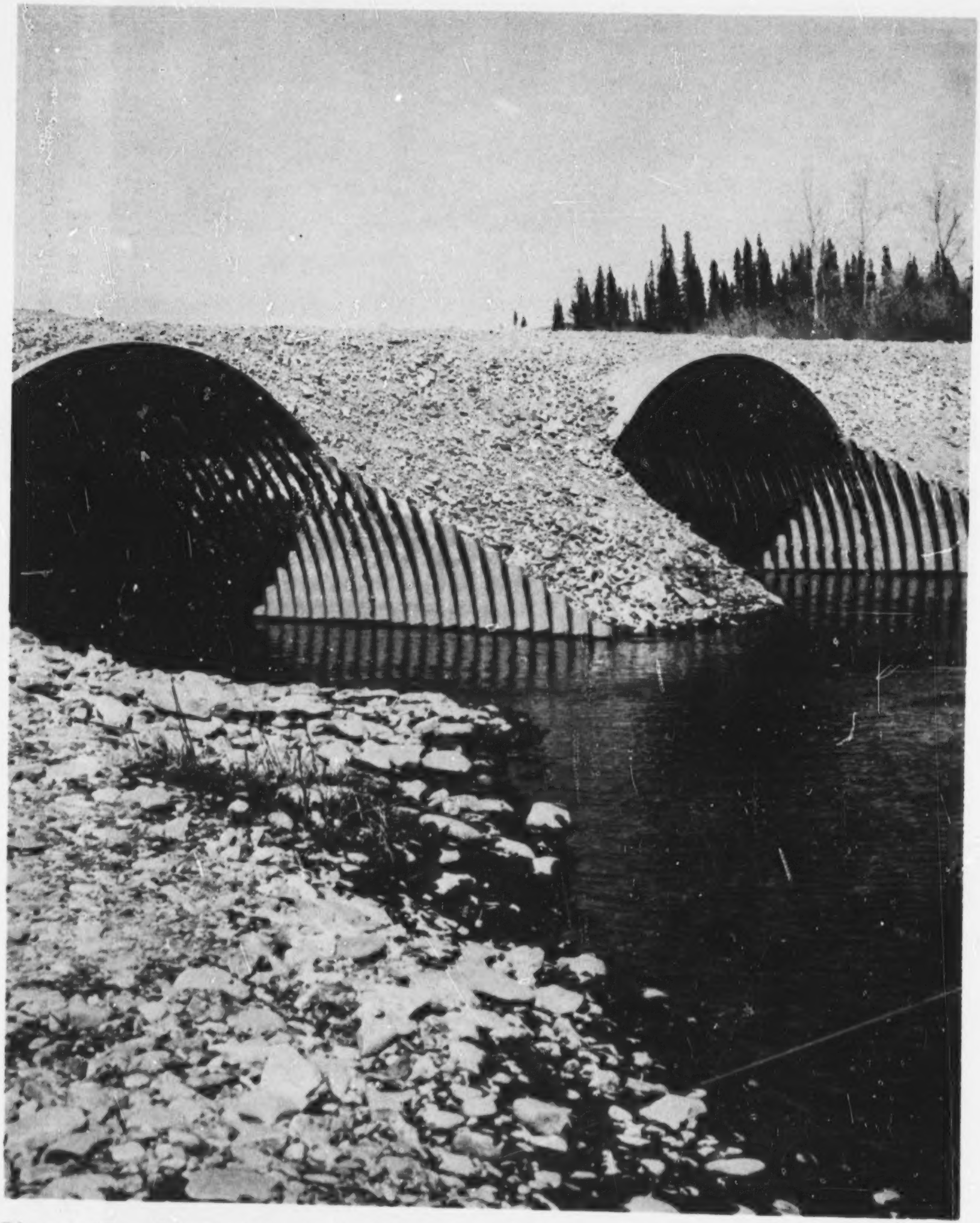

Figure 15. A properly designed and installed culvert. Note that there is ample capacity and sufficient depth of water to permit migrating fish to pass through. Such an installation will require a minimum of maintenance and will not act as a barrier to fish movement.

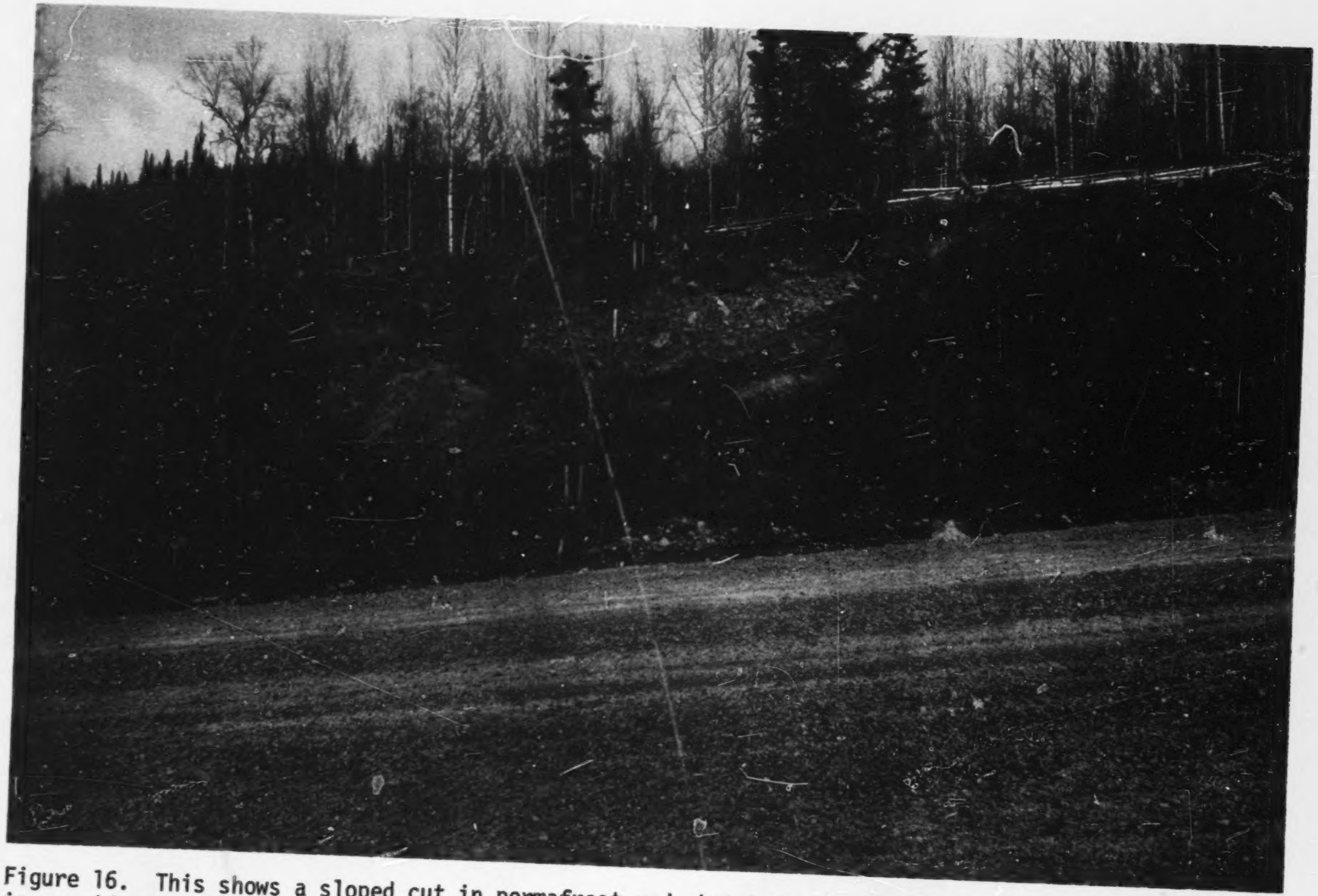

Figure 16. This shows a sloped cut in permafrost and what happens when the ice melts. Such a slope is considered good design by engineers in the absence of ice--what will eventually happen here is shown in a later figure. May 30, 1970.

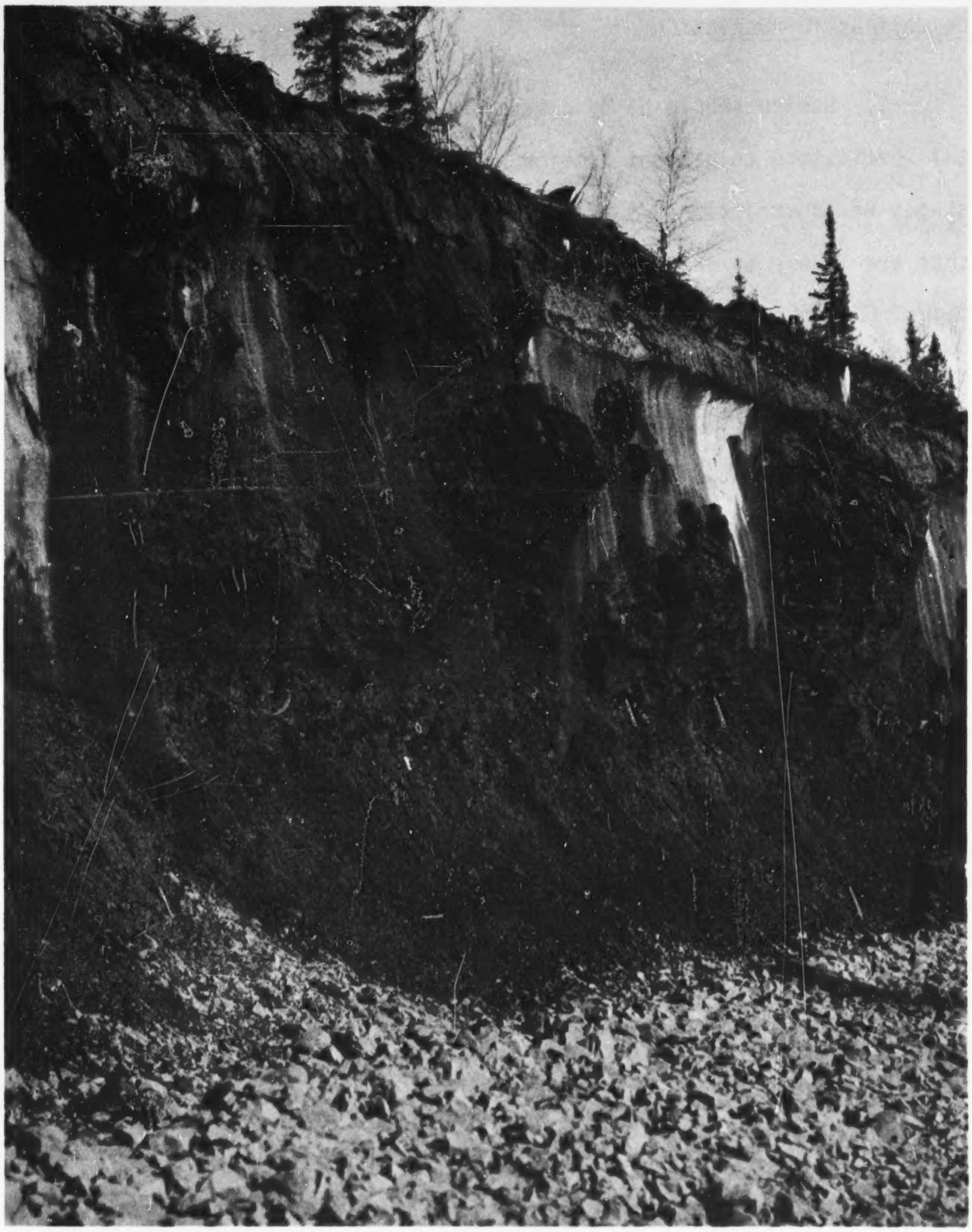

Figure 17. A vertical cut in permafrost as an alternate design to sloping. This procedure reduces cut volume and is stable as long as it remains frozen. (April 30, 1970) Thawing is in progress--very active where the sun strikes the face, much slower in the shade.

Guidelines for Design:

1. Design should be by a team composed of engineers and environmental specialists to prevent erosion and protect environmental values at all stages of construction. A plan for erosion control to protect raw cuts that are likely to erode should be an integrated part of the overall design. (See Bureau of Public Roads Instructional Memorandum No. 20-3-70.)

2. Locate construction camps in favorable terrain and design waste disposal systems to prevent water pollution in accordance with State standards; plan refueling and maintenance operations to preclude disposal of oily wastes to the environment.

3. Design the route to minimize the amount of clearing required for excavation and fill.

4. Select borrow areas to maximize use of other resources and minimize damage to waters, timber, and wildlife.

5. Design for subsequent use of borrow areas through revegetation and restoration to provide for recreation or other uses while maintaining esthetics.

6. In permafrost areas with high-ice silt, use overlay of sufficient thickness to control or retard the rate of thawing.

7. Give special attention to interfaces of dissimilar materials, i.e., ice to gravel. Promptly cover any ice surface cut to final grade.

8. Design culverts in such a way that fish passage will not be impeded.

9. Design bridges to minimize any alteration of stream hydraulics and use the longest feasible spans. The decision to use culverts must be made

only after careful design and consideration of ice and debris jamming the structure.

10. Provide for uninterrupted and safe upstream or downstream passage of fish. Any artificial structure or any stream channel change that causes a permanent blockage to migration of fish should be provided with a permanent fish passage structure that meets all Federal and State requirements. The proposed design should be submitted at least 90 days in advance of construction.

11. Water velocities at medium discharge should not be excessive in any part of a culvert on streams classified as fish migration, spawning, or rearing. Solutions to this problem may be derived during design by a competent fisheries biologist.

12. Conduct studies to determine the most feasible route and best construction methods through permafrost areas to prevent permafrost degradation that could result in progressive local land form changes.

13. Except at approved crossings, the road should be located to provide a buffer strip of undisturbed land along the stream as determined by State Fish and Game authorities. Request for exceptions to this provision should be submitted in writing at least 30 days in advance for approval. The request should include a description of the design criteria and time necessary to restore or enhance the stream habitat.

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SECTION IV

CONSTRUCTION ACTIVITIES

It is during the actual construction process that most environmental damage is done by contractor personnel. All the proper safeguards designed into the plan are useless unless the contractor personnel operate within the constraints of the design. Contracts should include provisions for permanent pollution control and must be included in the estimate of costs just as are other construction costs. Instructional memorandums issued by the Bureau of Public Roads (B.P.R.) go one step further and are insisting that costs of temporary pollution control during construction be included as a contract item. When interim measures to prevent erosion during the construction period are neglected considerable pollution can result.

Before construction starts, preferably after the contracts are let and the contractor is mobilizing his forces, conferences with labor leaders, inspection teams, superintendents, and resource managers should be held. Such conferences should point out why certain procedures, heretofore considered acceptable, are no longer condoned. The object is not to set up a list of "do nots" but to explain why new procedures are being used and why these are to the ultimate benefit of all concerned. If the equipment operators are aware of the need for, and are actually participating in, environmental protection, the need for detailed inspections is lessened. Unless management and labor enter into the spirit of environmental protection, no amount of inspections can prevent some damage. The ultimate objective is to motivate each person concerned that his efforts

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to protect the environment will pay off in a better place in which to live.

Since much of the rationale for adhering to accepted practices for environmental protection was given under previous headings, much of what follows will consist of enumerating guides or instructions. Many of these guidelines are taken directly from the stipulations written by the Bureau of Land Management to cover road and pipeline construction of the proposed trans-Alaska pipeline by Alyeska Pipeline Service Company (ALPS). These stipulations were prepared to protect the total environment which this project will traverse and are the result of collective input of several State and Federal agencies.

Surveying and Right-of-Way Clearing:

1. Prior to, and during construction activities, construction personnel should be briefed on environmental problems by designated specialists. These briefings should include fire prevention and suppression training for all personnel.

2. During establishment of center-line, grades, and boundaries, keep equipment on the right-of-way whenever possible. Utilization of equipment off established routes leads to erosion and permafrost melting without control.

3. Cut all timber close to the ground to preclude unsightly stumps remaining after completion of the project. Fall the timber into the right-of-way and away from water courses. (Figures 18 and 19 show the appearance of these early activities, September 1969.)

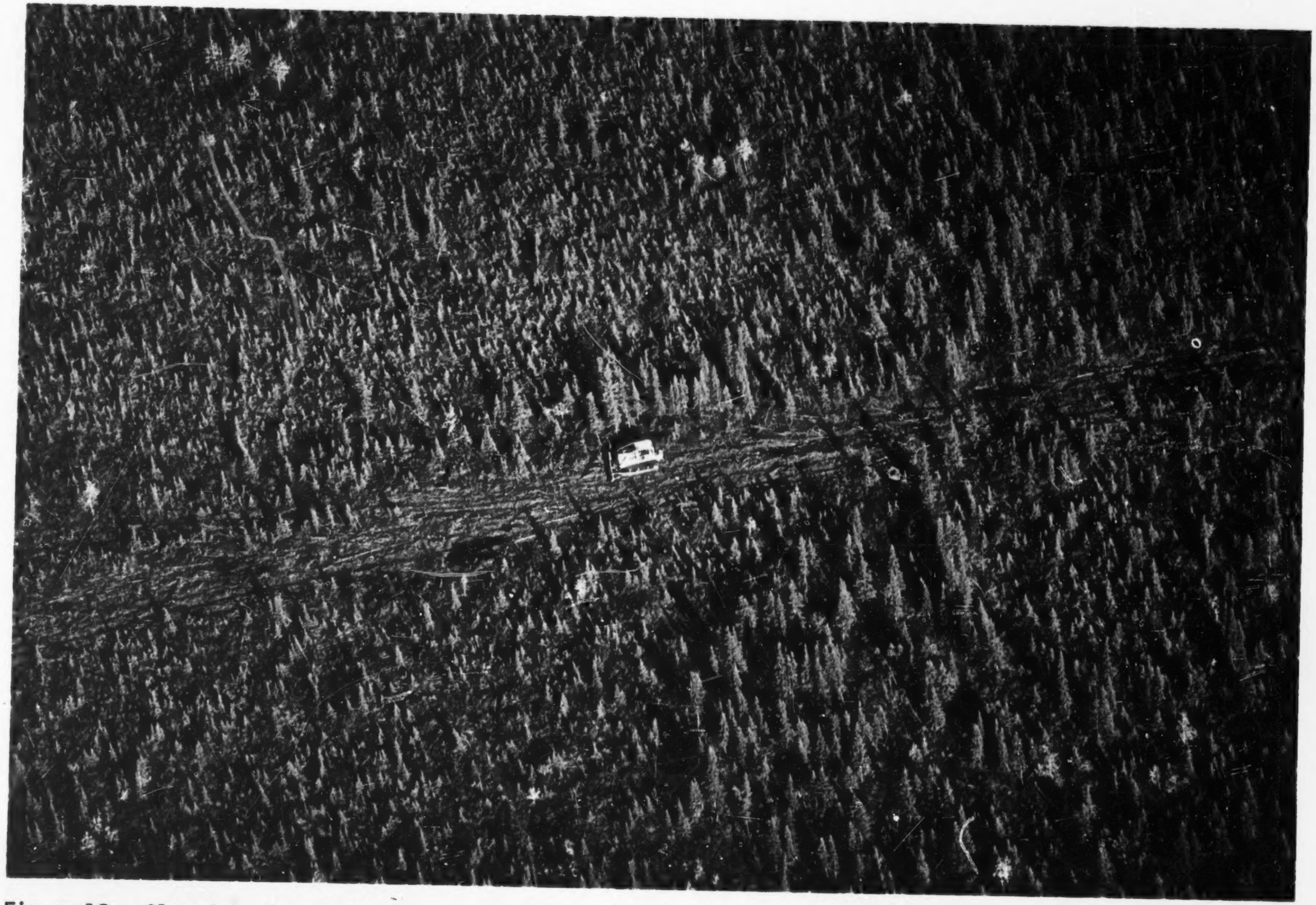

Figure 18. Clearing the right-of-way preparatory to placing overlay; the trees are knocked down but left in place. This has proved to result in maximum stability if overlay is thick enough.

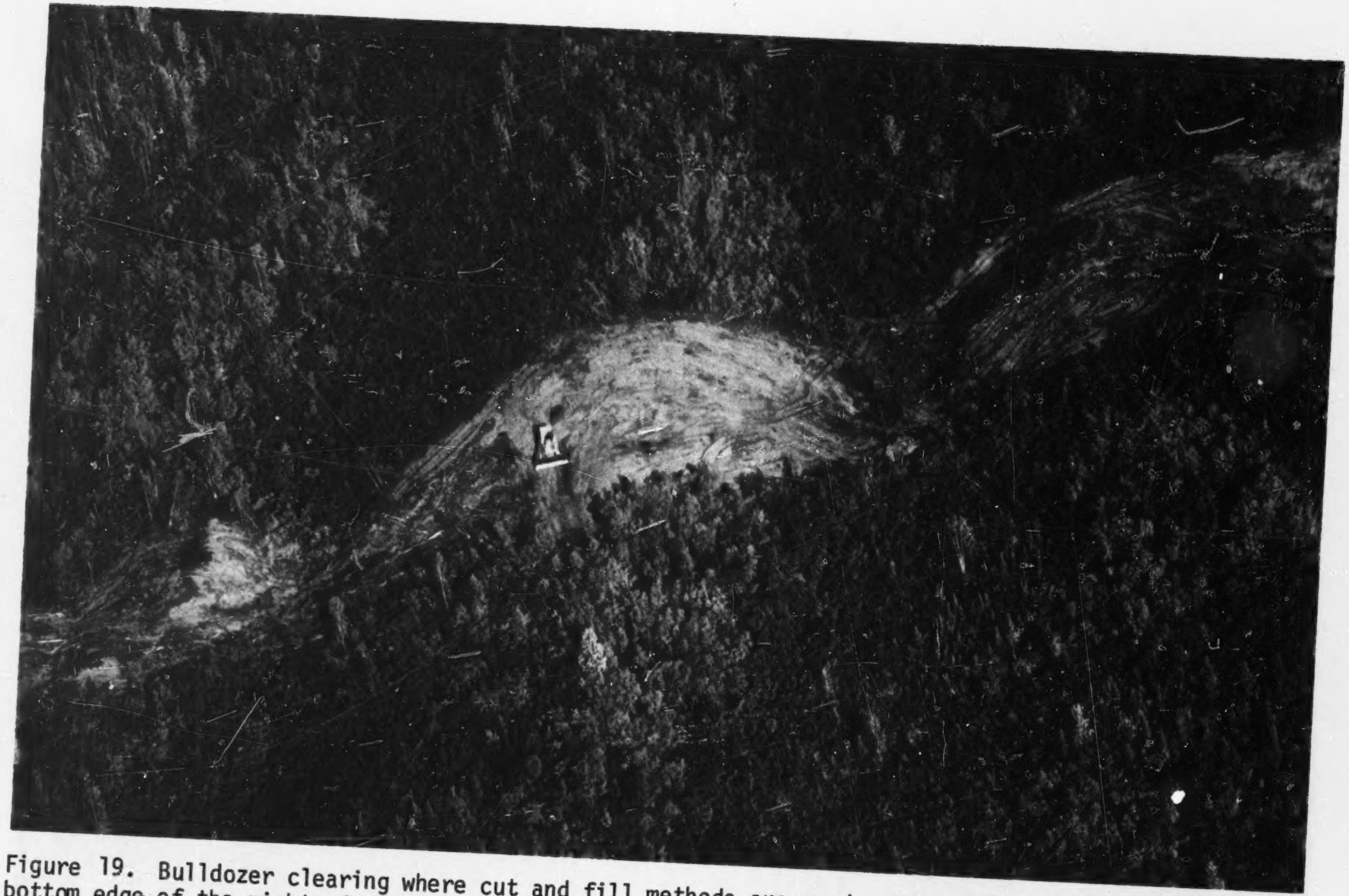

Figure 19. Bulldozer clearing where cut and fill methods are used. The trees are pushed to the bottom edge of the right-of-way and will be burned during the winter; fire hazard is extreme during the summer and fall in central Alaska. A better means of disposing of this debris would be chipping and spreading on raw cuts and fills.

4. The organic mat should be preserved where the design calls for overlay. This procedure is the most effective method to control permafrost melting.

5. Logs should not be skidded or yarded across any stream without prior approval and log landings should not be located on the banks of any live stream. Where heavy equipment would be detrimental to existing conditions, hand clearing operations should be used.

6. All debris from clearing operations should be disposed of by burning, chipping, or other agreed upon method; none of this debris should enter streams.

7. Timber or other vegetation outside of the right-of-way clearing boundary should not be cut or otherwise removed.

8. Logs having value to previously agreed upon persons should be neatly stacked along the edge of the right-of-way

Earthwork

1. When it becomes necessary to excavate soils with high ice content make vertical cuts and do not attempt to slope them in the usual manner. Observations of the Livengood-Yukon River road in the summer of 1970 clearly show that vertical cuts are superior to slope cuts. (Figures 21 - 28 show the appearance of permafrost at various stages of melting under the two treatments.)

2. Leave all the vegetal mat possible on the edge of the cut. This mat is effective in protecting the upper four to six feet of the cut as melting causes the cut to recede. (Figures 29 - 32 illustrate the progressive appearance of this melting.) Thawed soil shifting down to the toe

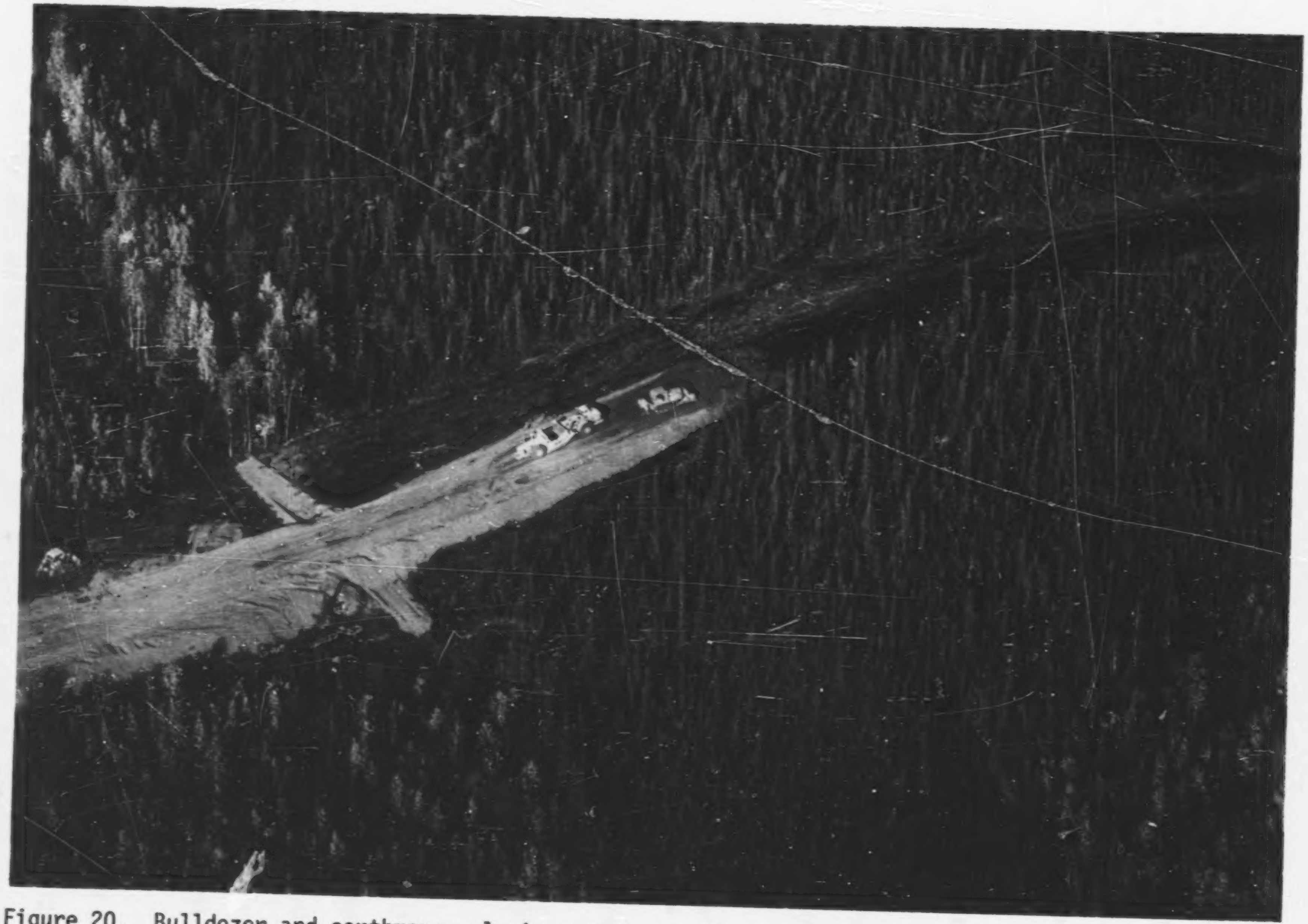

Figure 20. Bulldozer and earthmover placing overlay at the head of a fill.

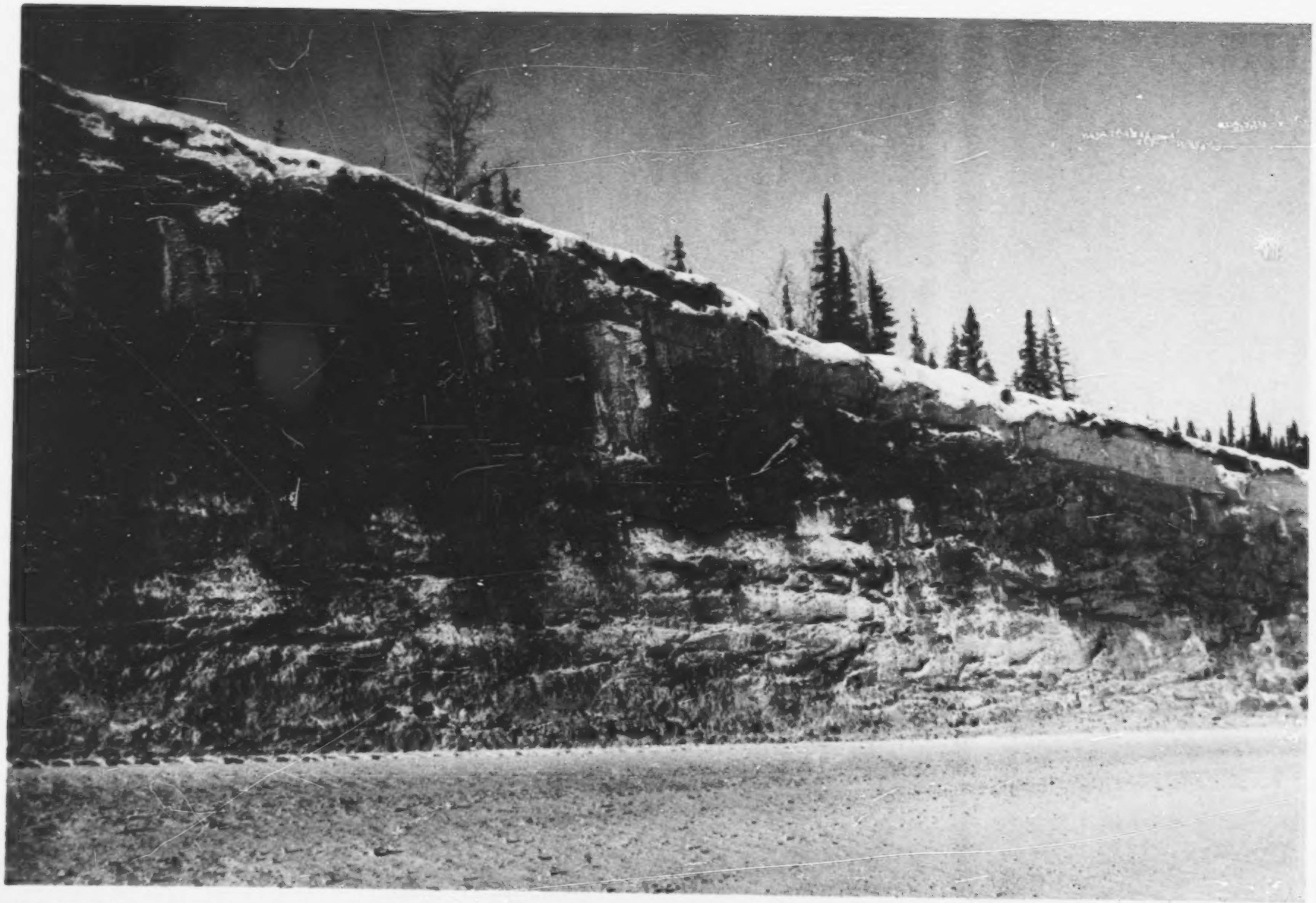

Figure 21. Vertical cut in frozen silt intercalated with lenses and seams of ice. This exposure is about 40-50 percent ice and was not melting at the time it was photographed. March 3, 1970.

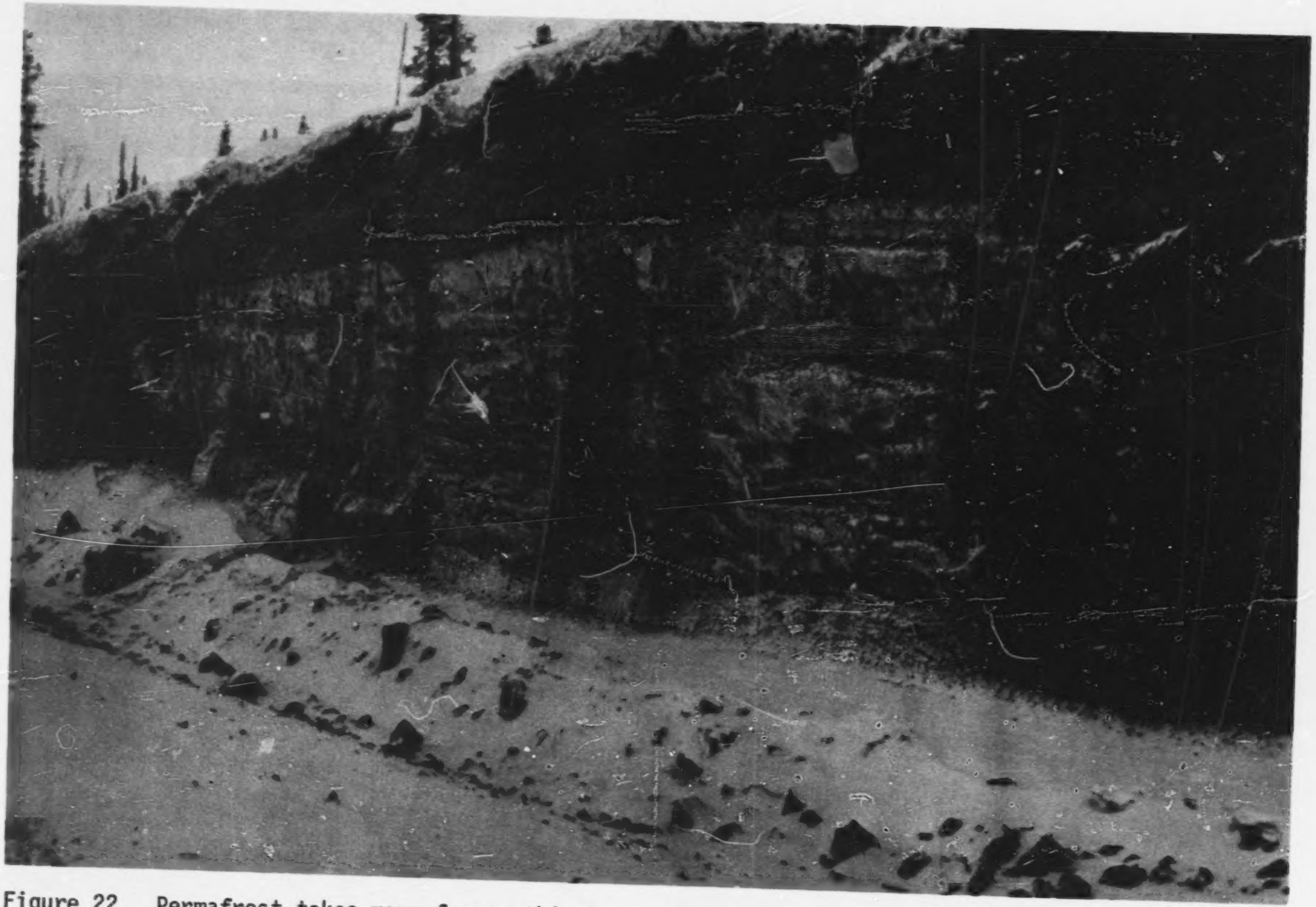

Figure 22. Permafrost takes many forms; this is massive ice; the roadbed is on almost pure ice. March 3, 1970.

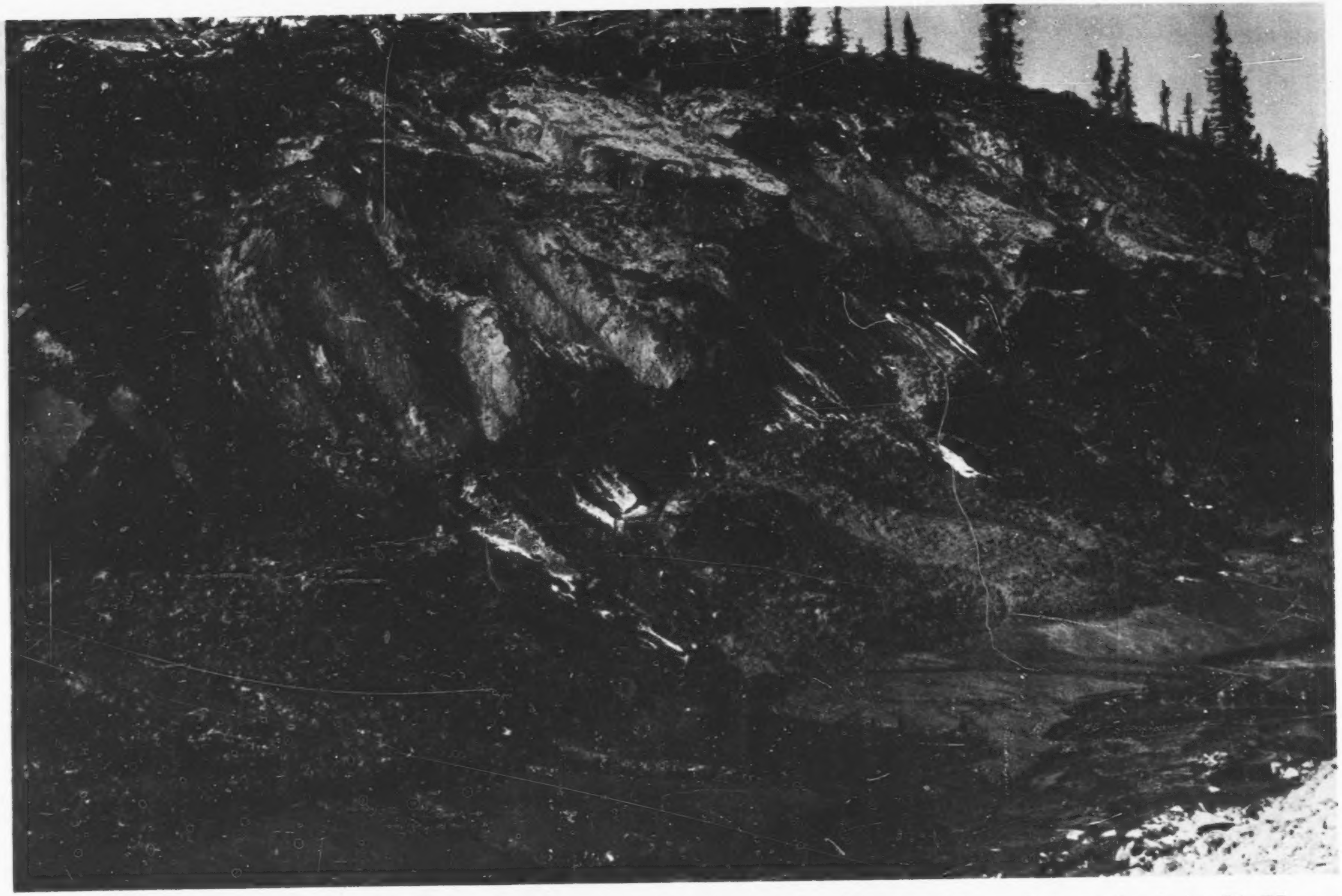

Figure 23. Melting permafrost at a sloped cut well exposed to the sun where ice content is 50-75 percent. Released water carries the fines in suspension and deposits them along the road or in the nearest drainageway. Such a cut poses a maintenance problem for some time. May 26, 1970.

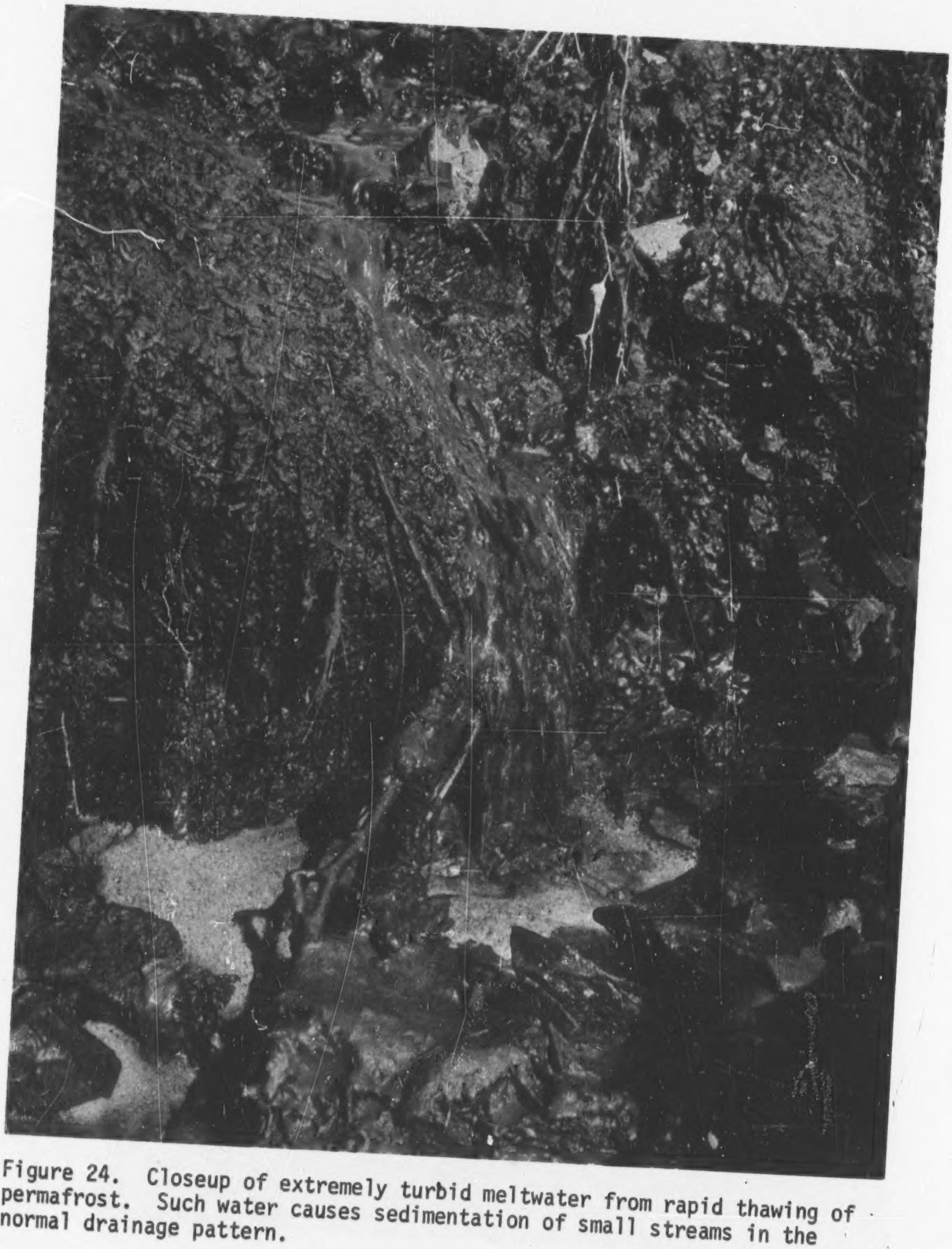

Figure 24. Closeup of extremely turbid meltwater from rapid thawing of permafrost. Such water causes sedimentation of small streams in the normal drainage pattern.

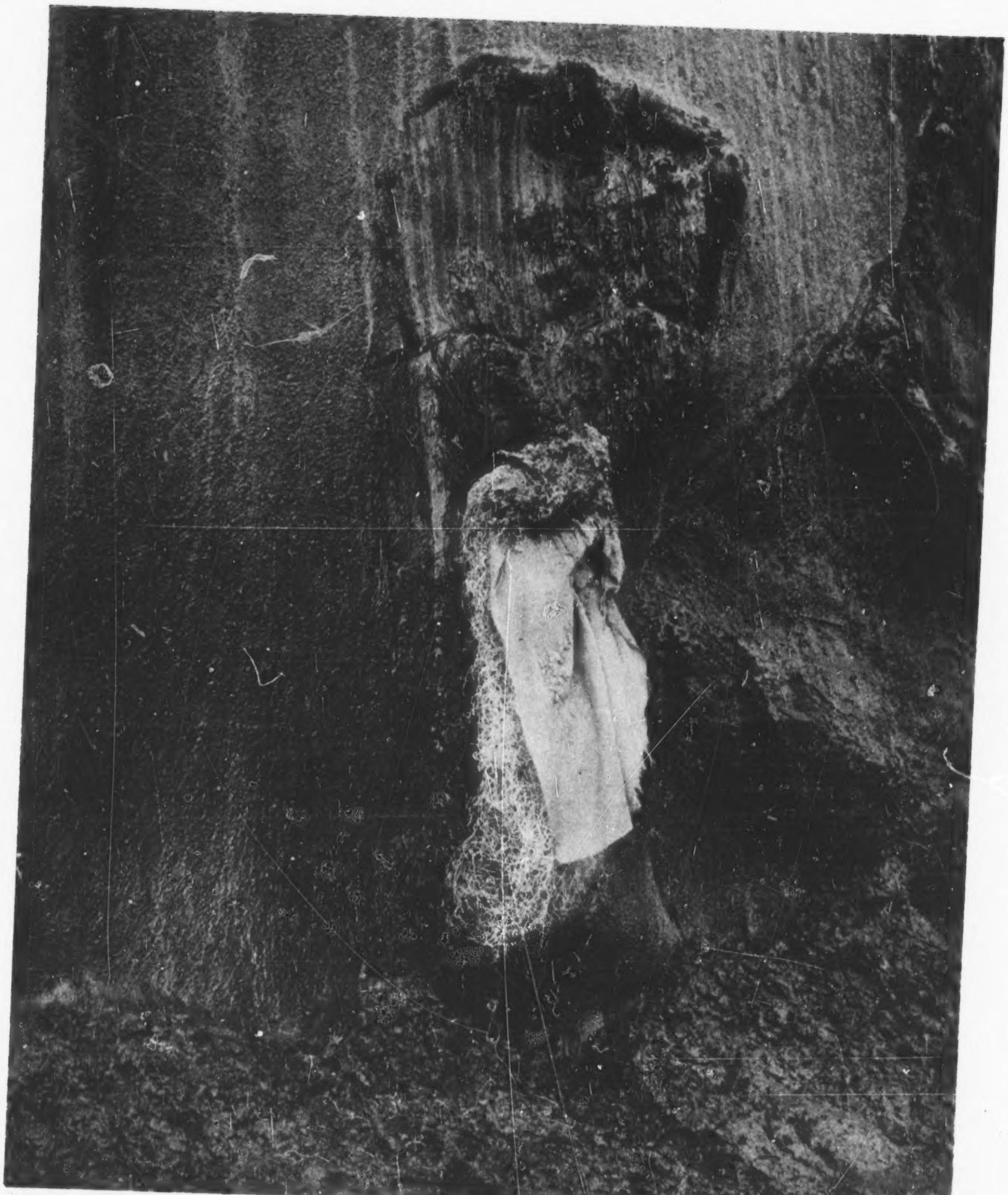

Figure 25. Closeup of massive ice and silt with a piece of excelsior attached to it. This form of insulation appeared to be effective because the silt covered by it is receding slower than the unprotected ice. (Silt, however, appears to melt slower than pure ice.) A month later this exhibit had disappeared by melting. April 30, 1970.

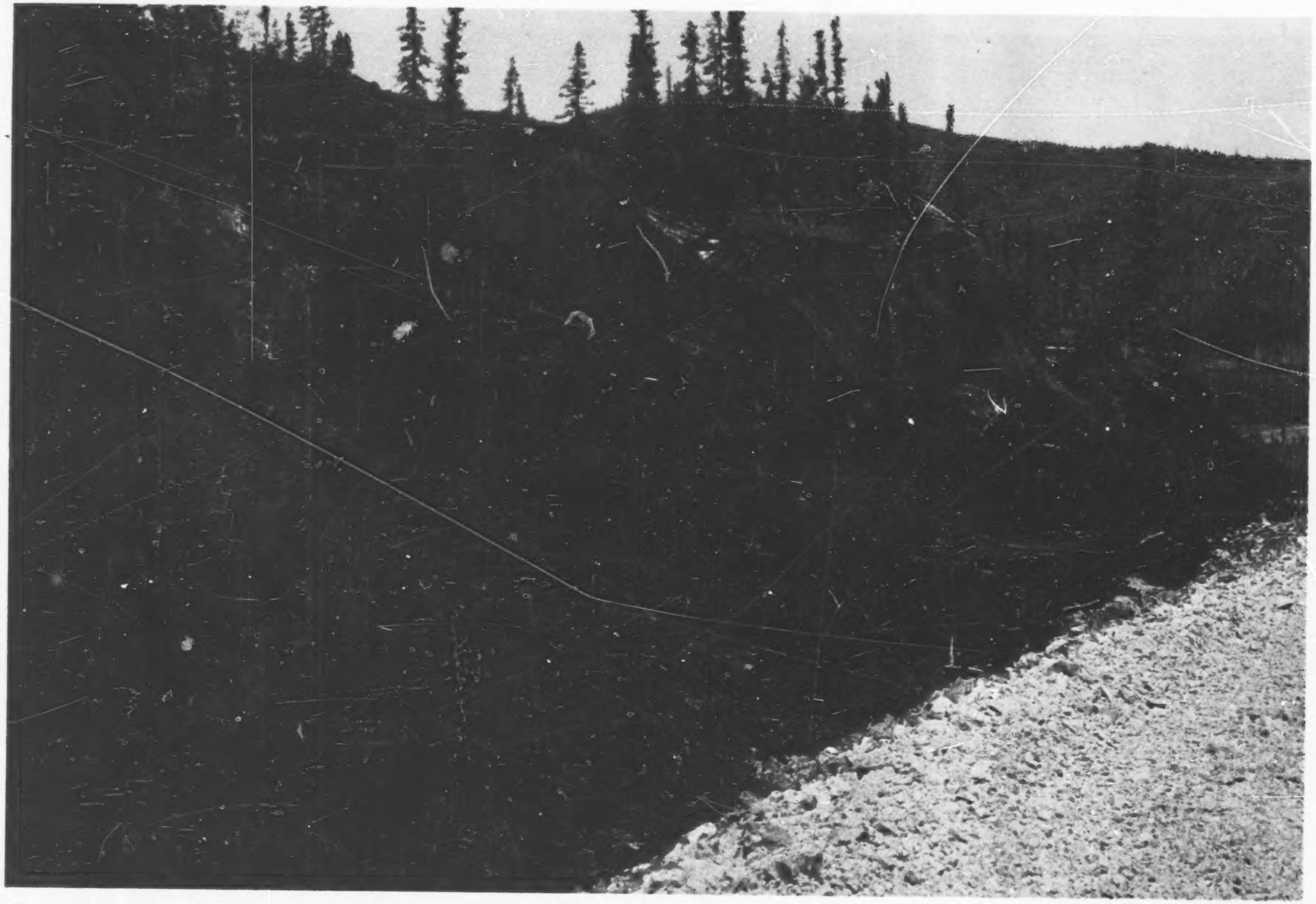

Figure 26. The same cut shown in Figure 22 three months later. Note the lack of vegetal mat and continuously exposed ice; toe of slope is well protected by material released by thawing. July 2, 1970.

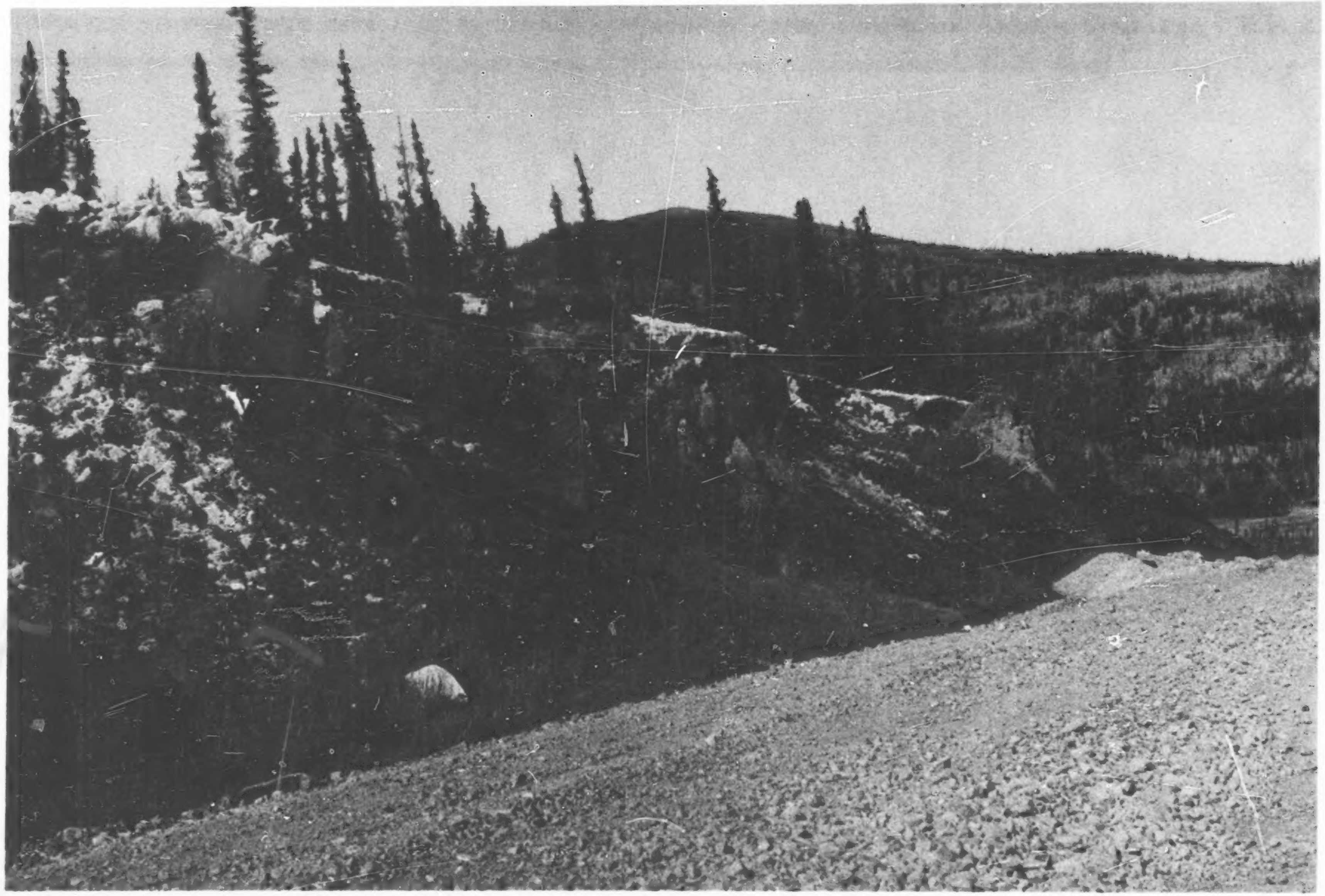

Figure 27. The same cut on September 3, 1970. Stability has not been fully achieved even though the face has receded 30-40 feet.

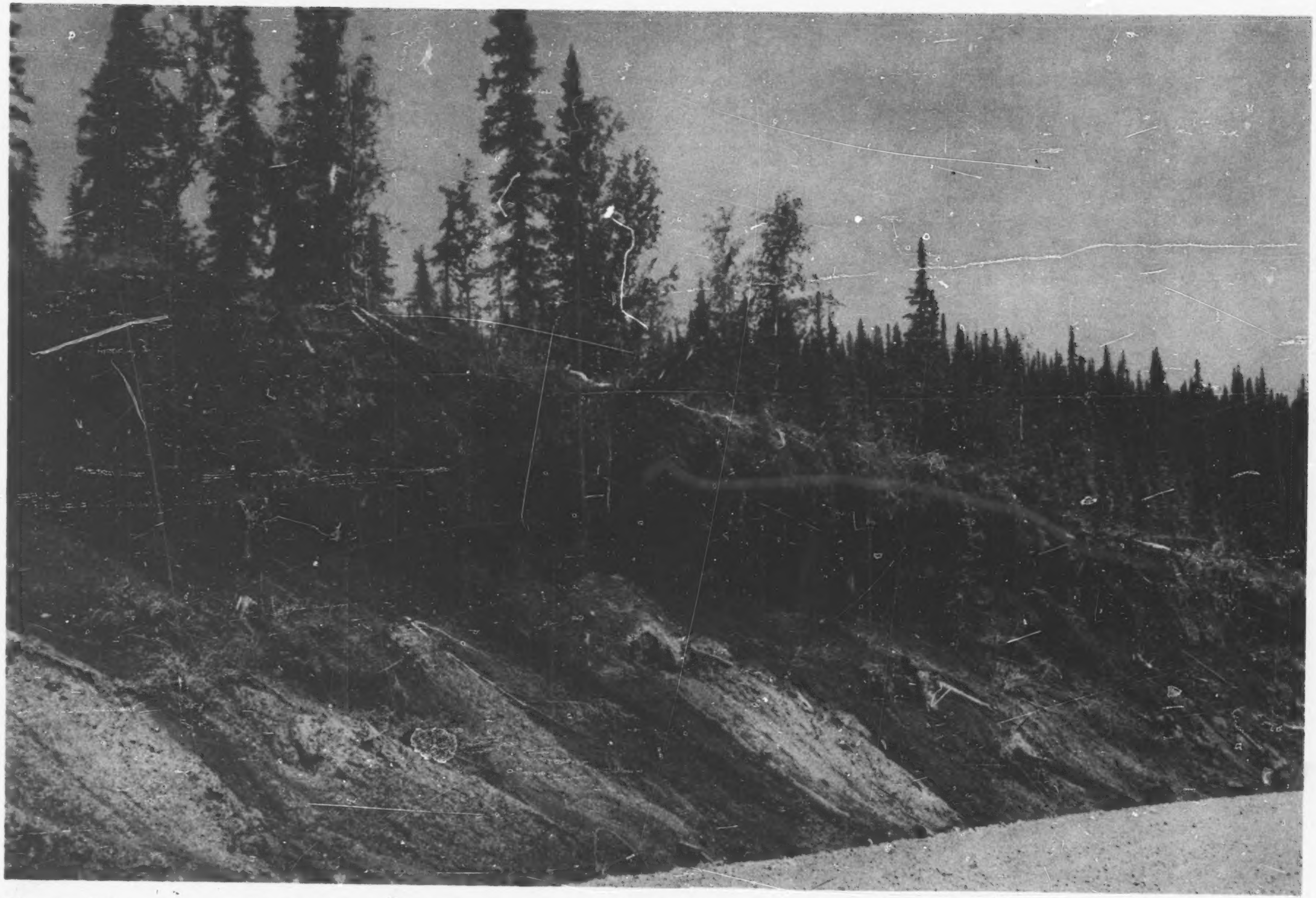

Figure 28. A moderately deep vertical cut with a vegetal cover overhanging. Melting is still active but is slower because of shading, mud flows were less evident. July 24, 1970.

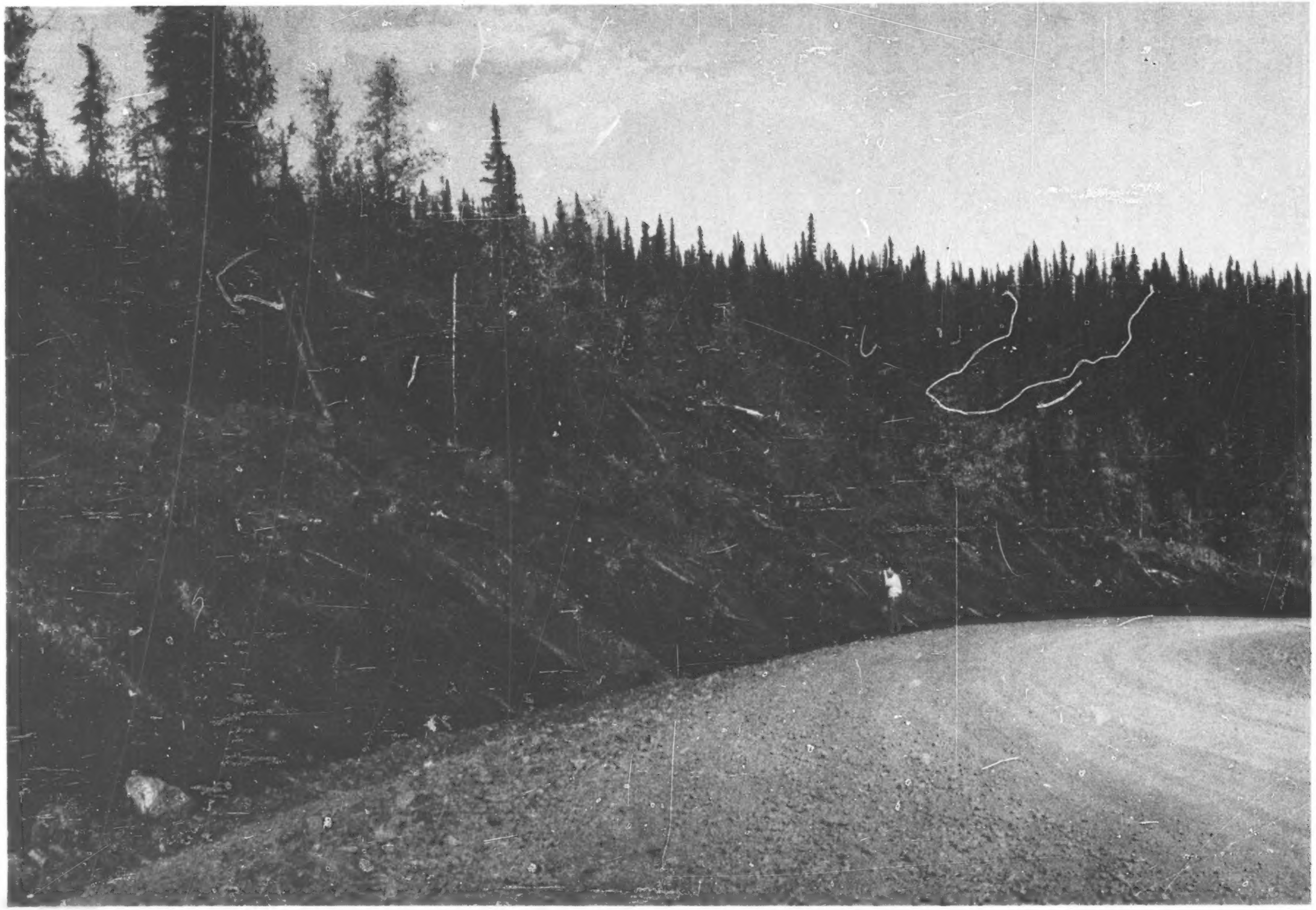

Figure 29. The same cut on September 3, 1970. Stability is not complete but is in an advanced state.

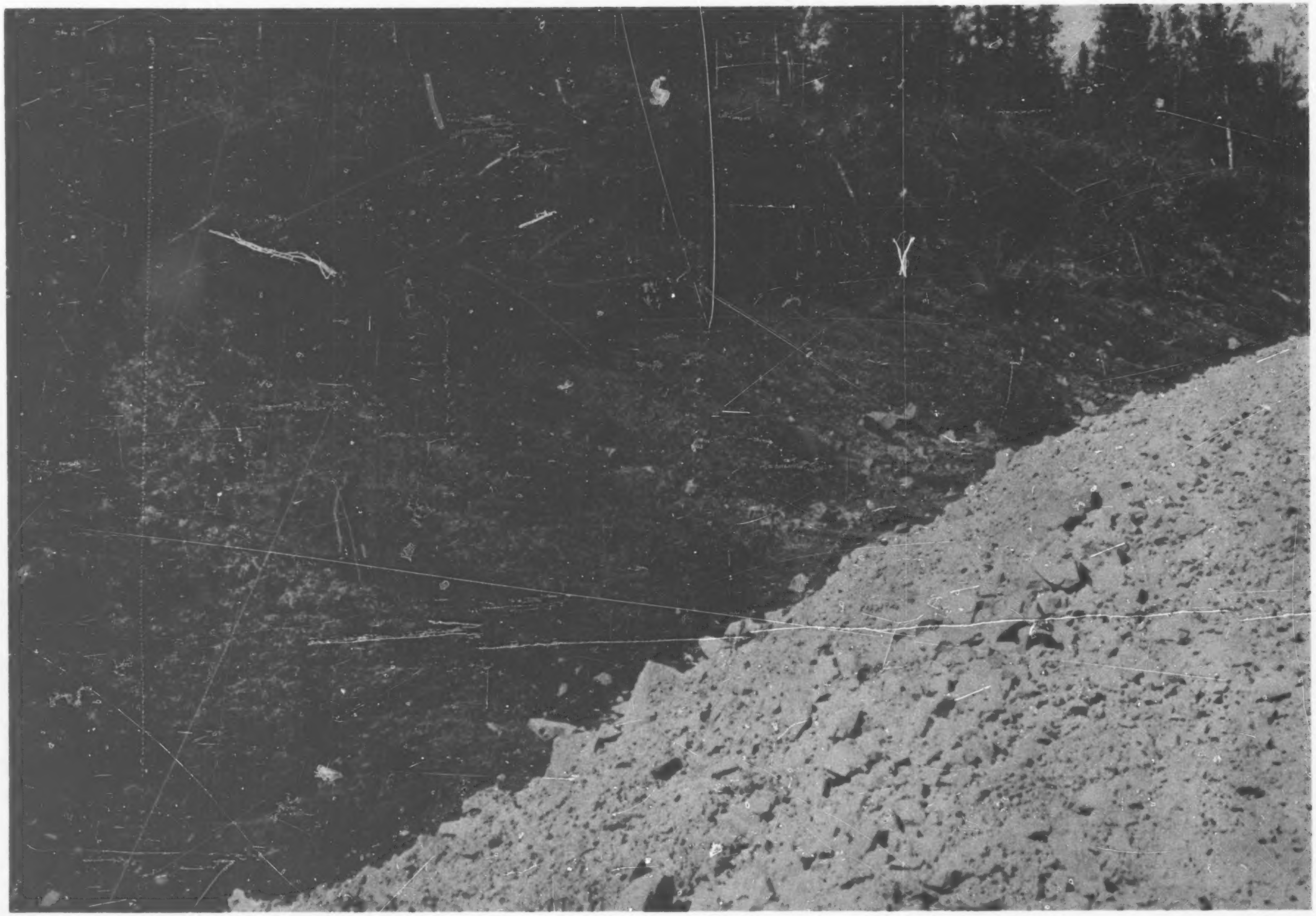

Figure 30. By July 24, cuts 8-10 feet deep with a good overhanging vegetal mat were nearly stabilized.

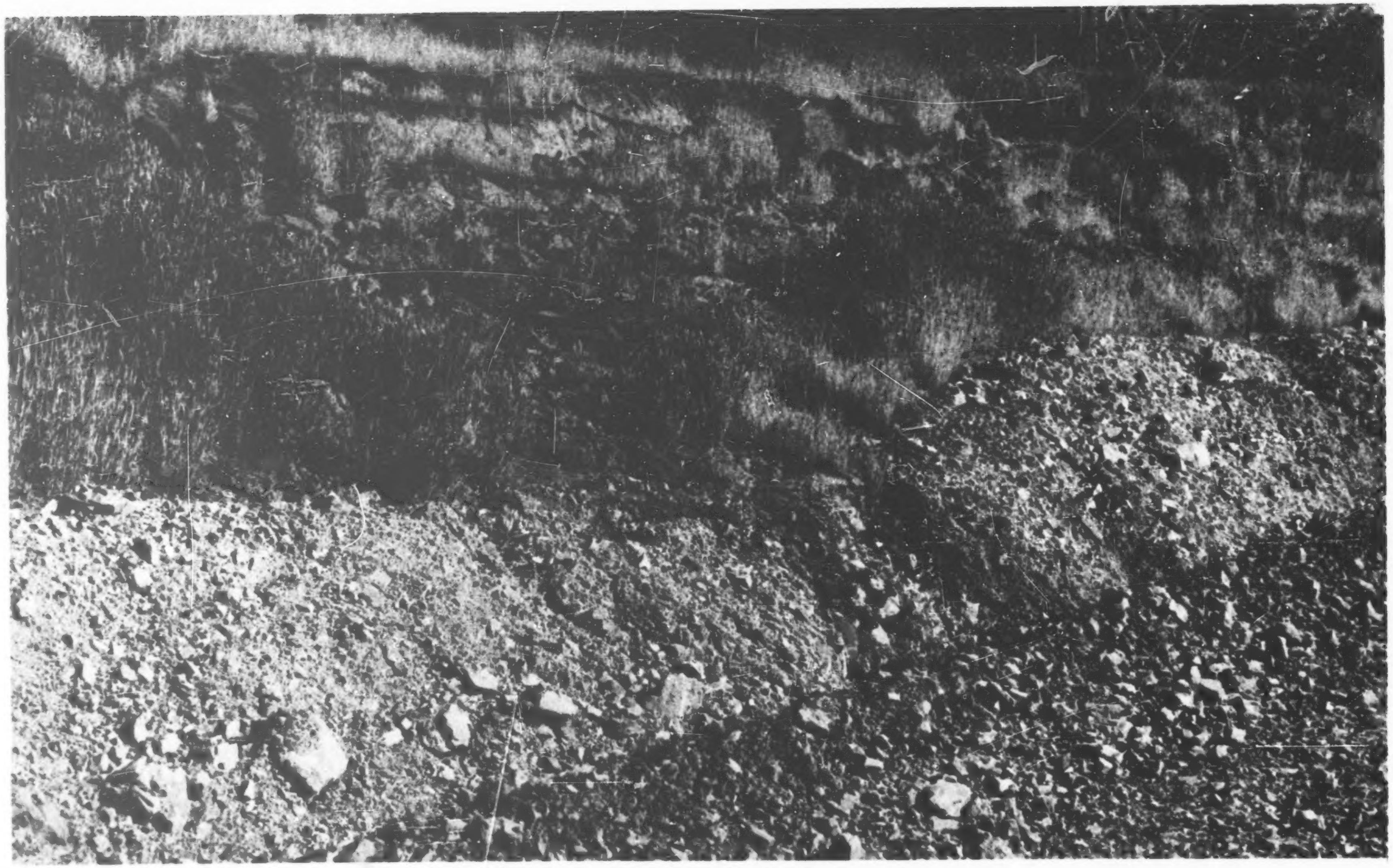

Figure 31. Good stabilization of a sloped cut by September 3. Here the cut was seeded in July and oats established on the silt overlying massive ice; as melting continued, ice support of the silt was removed resulting in the stepped slumping shown here. Note the absence of a natural vegetal mat such as shown in Figure 30; such a mat is not preserved with sloped cuts; stability is hastened in vertical cuts.

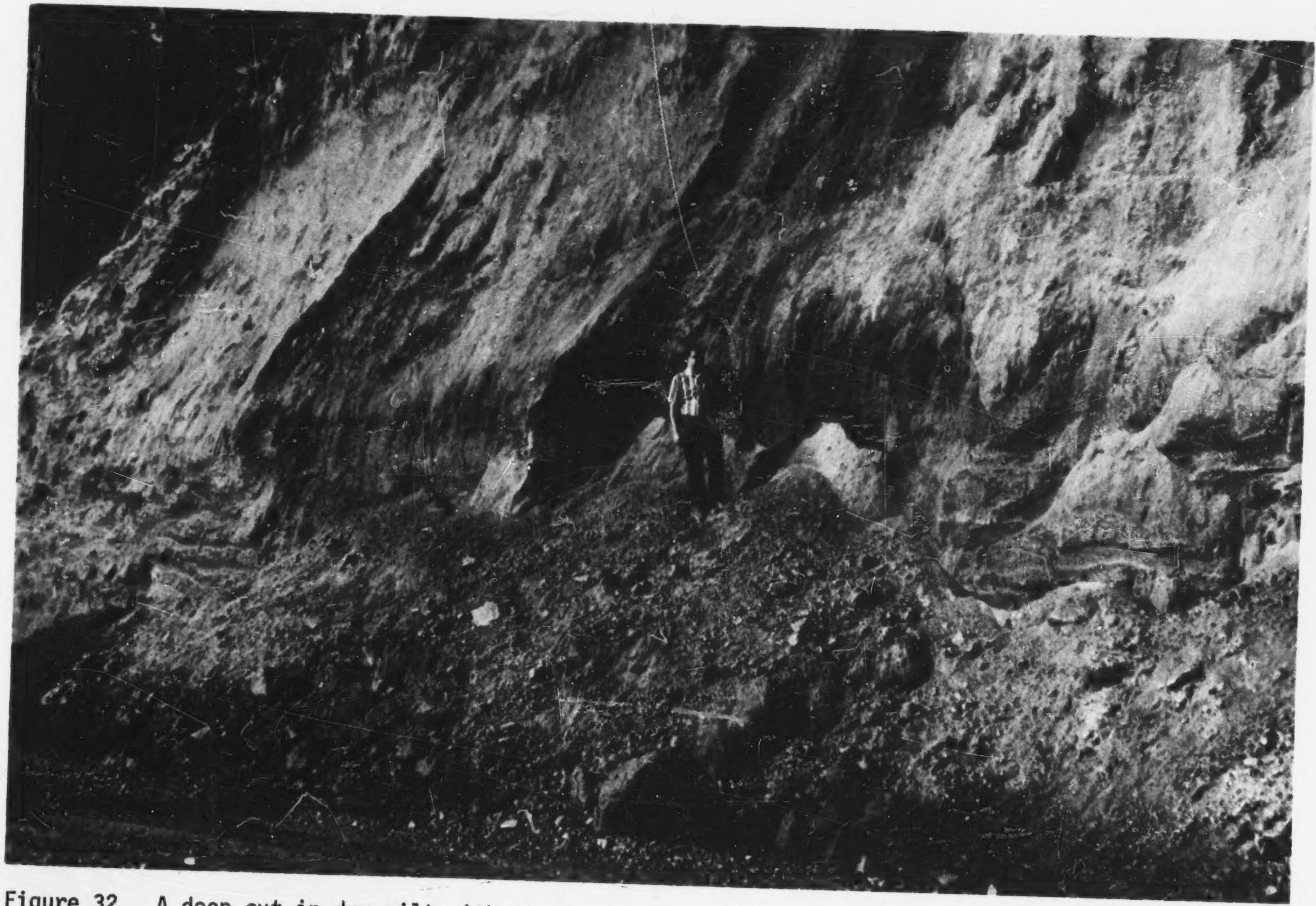

Figure 32. A deep cut in dry silt without massive ice; this silt was frozen and melts on exposure but does not pose a pollution problem because it lacks water to carry away loosened silt. July 24, 1970.

of the cut protects the lower part and where the cuts were not more than eight to ten feet deep they appeared to be well stabilized by the end of July 1970. This fallen material retards the melting rate and permits melt water to drop its load and run clear instead of highly turbid.

3. Keep high-ice waste piles compact and covered with some form of insulating material after all waste is in place. If melting is too rapid, these waste heaps act as mud flows which contribute heavy sediment loads to adjacent streams. (See Figure 33.)

4. Areas having soils that are susceptible to slides and slumps, excessive settlement, severe erosion and soil creep, should be avoided wherever possible. However, if these areas cannot be avoided, or are encountered unexpectedly, design construction to insure maximum stability. Continue soil investigations during construction activities.

5. Construction methods should be conducted to prevent degradation of the permafrost in areas where such degradation would result in detrimental erosion or subsidence. (Figures 34 - 37 show what good procedures can accomplish.)

6. Application for the purchase of construction materials should be made to the proper State or Federal offices in accordance with regulations. Such application includes a materials sale contract with advance payment and submittal of a mining plan for approval prior to removal of materials from public lands.

7. Upland materials and existing material sites should be utilized in place of clearwater stream materials when reasonably available.

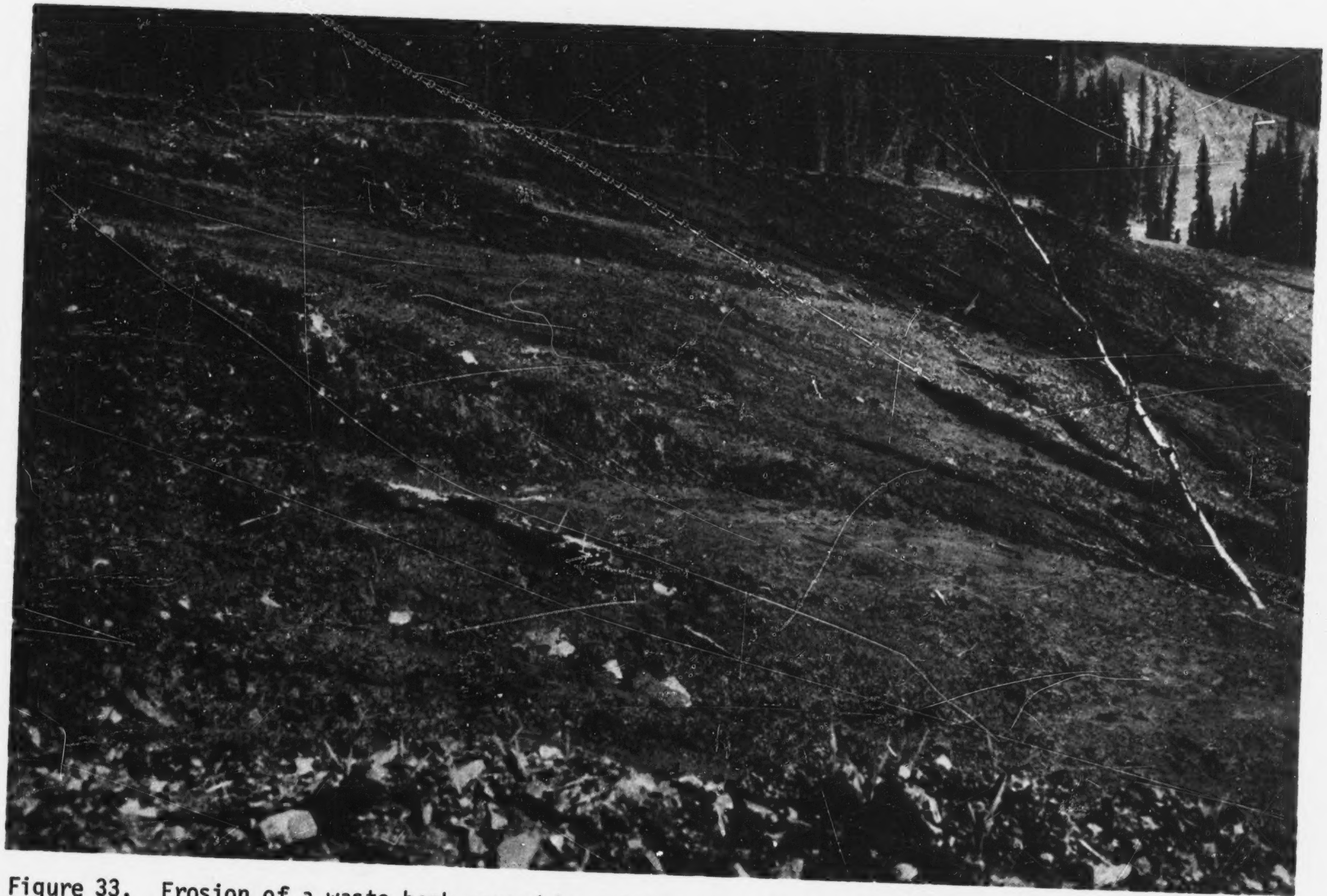

Figure 33. Erosion of a waste bank caused by melting of ice contained in the removed cut material. Such banks should be protected by an overlay of insulating material to retard melting otherwise much of this material enters the drainage system as unnecessary sediments. July 24, 1970.

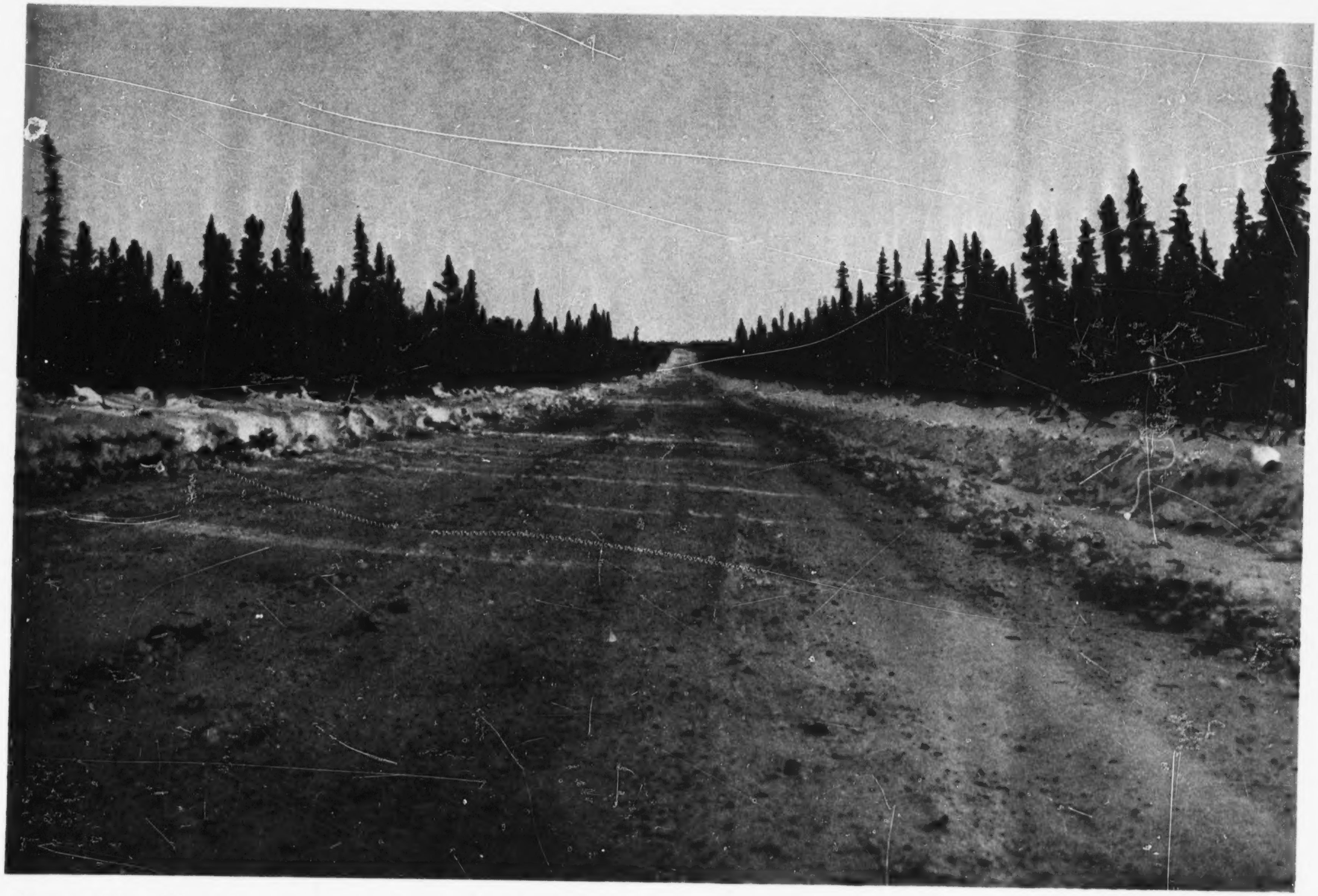

Figure 34. Winter road construction with thin overlay which will be built up to 5 feet before thawing causes instability. March 3, 1970.

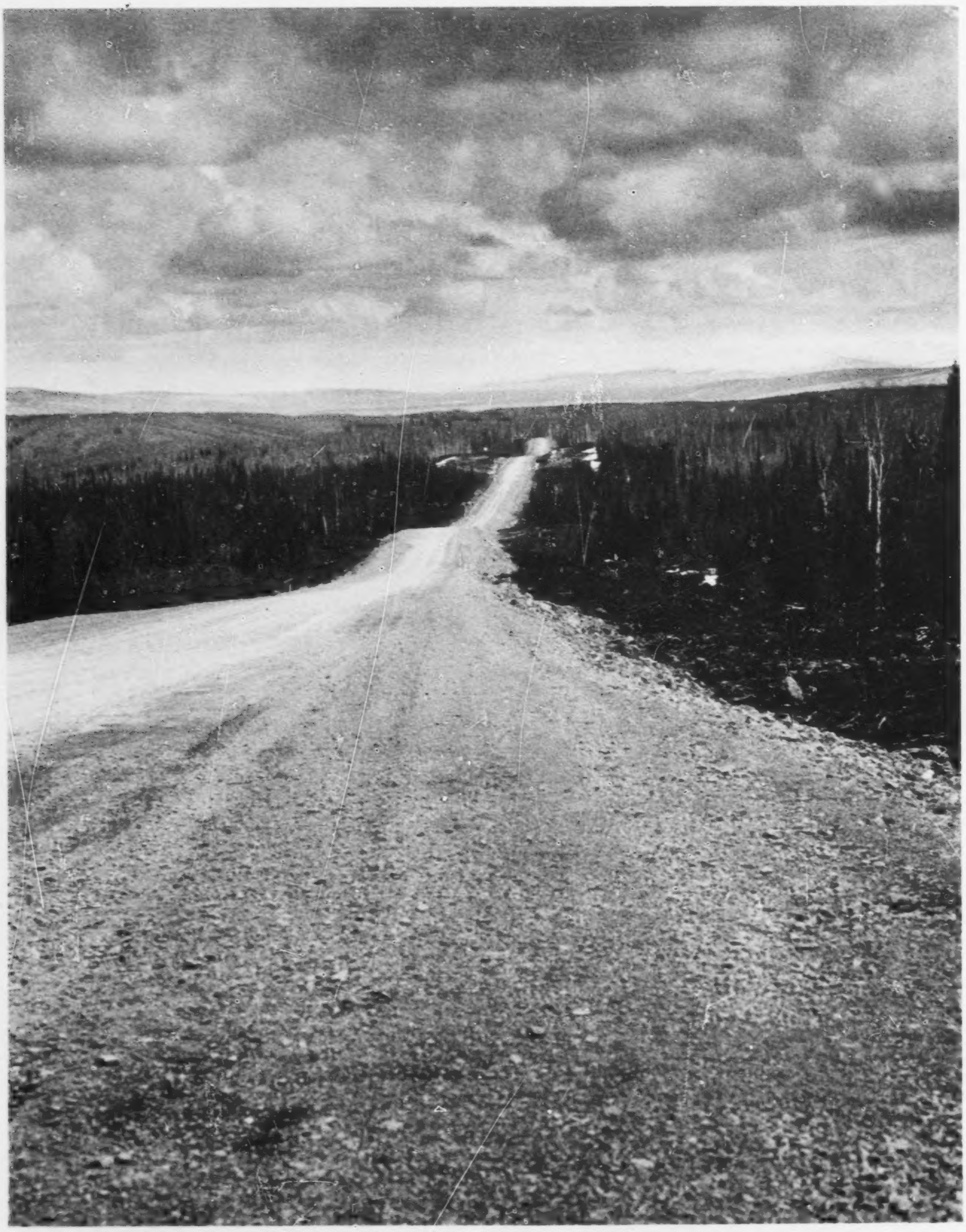

Figure 35. A finished road built with overlay; this road is nearly up to grade and should withstand heavy traffic. Note the clean right-of-way and the undulating roadbed instead of the usual cut and fill. May 26, 1970.

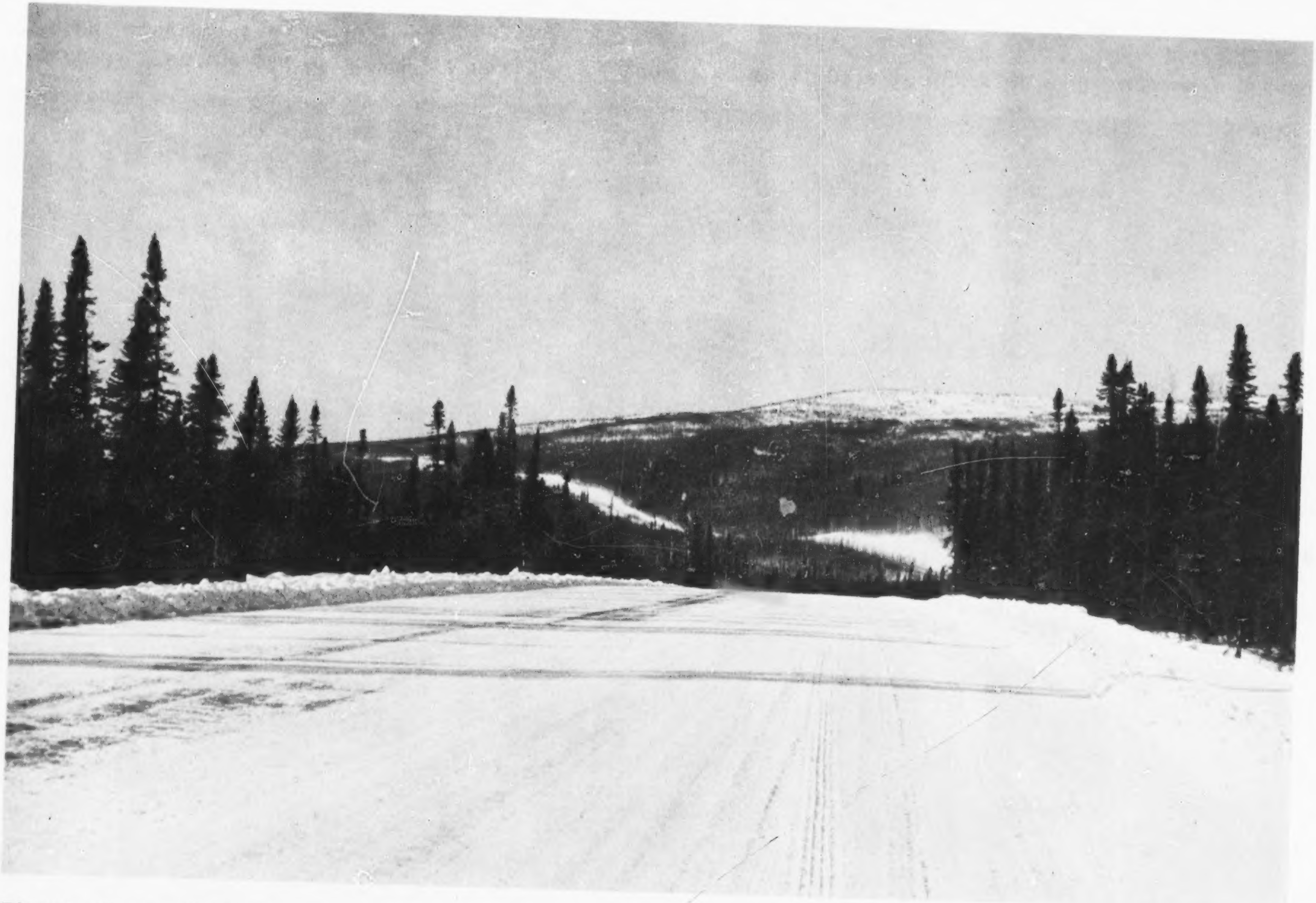

Figure 36. A finished road built on cut and fill principle; this road is designed for heavy traffic and should withstand its projected load. March 3, 1970.

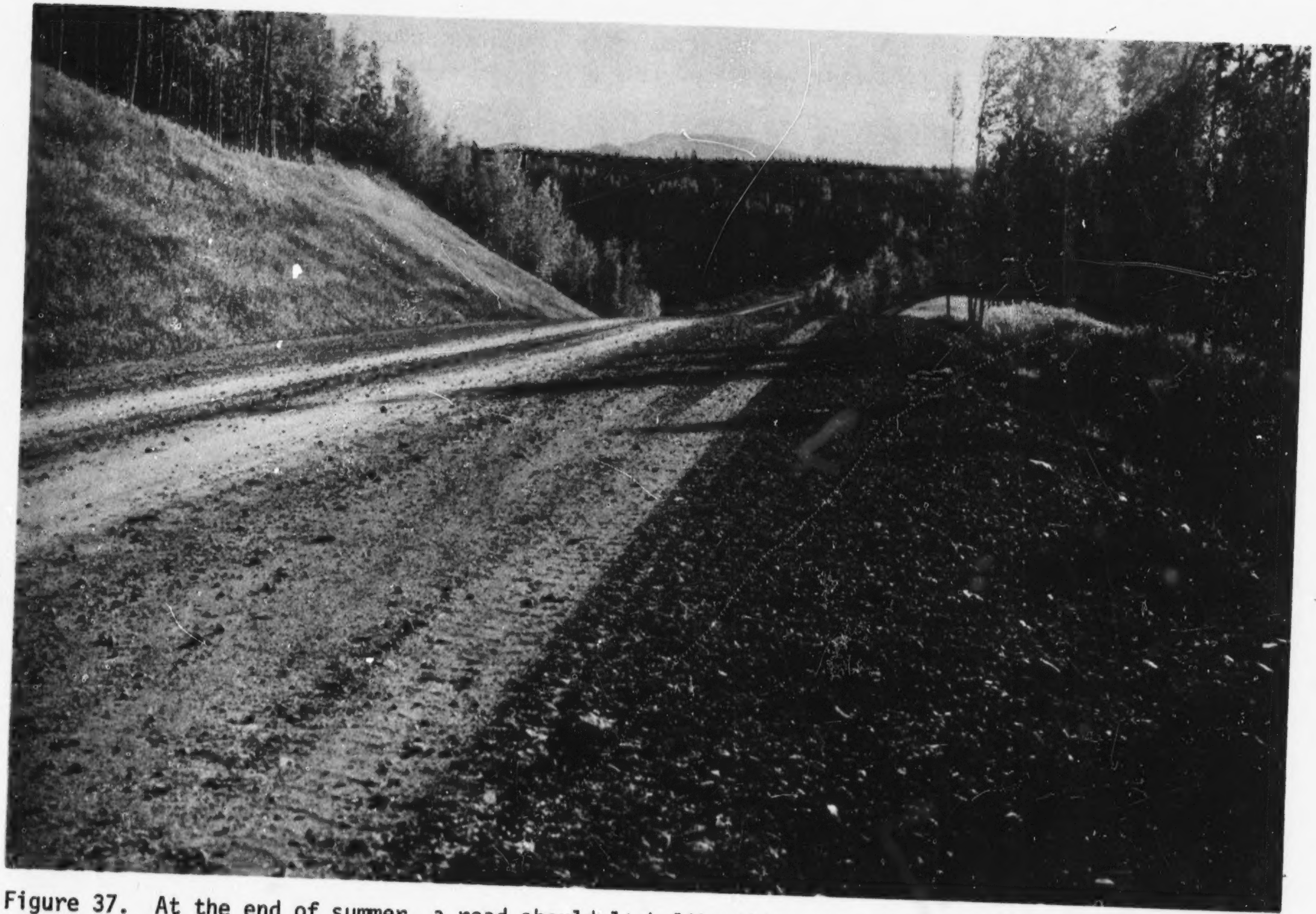

Figure 37. At the end of summer, a road should look like this; note the grassed banks and well-graded roadbed. September 3, 1970.

8. Material borrow sites must be screened from the road right-of-way by leaving a strip of natural vegetation. Exemption from this requirement must be authorized in writing.

9. Where haul roads from borrow areas intersect the right-of-way, a screen of vegetation, native to the specific setting, should be established unless waived in writing.

10. Shape material site boundaries in such a manner to blend with surrounding natural land patterns. Regardless of the layout of material sites, primary emphasis should be placed on preventing damage to vegetation and soil erosion.

Structures

1. No blasting should be permitted underwater, or within one-quarter mile of streams or lakes, without a permit from the Alaska Department of Fish and Game. The application for permit should set forth blasting locations, types and amounts of explosives, date or dates of blasting, and the reason for blasting. Provisions should be made for emergency cases where unforseen conditions may call for the use of explosives not included in the original plan.

2. Where channel changes cannot be avoided in designated anadromous fish spawning beds, construct new channels according to standards supplied by the State Fish and Game personnel. Protect spawning beds from sediment from all construction activity. Where soil material is expected to be suspended in water as a result of construction activities, construct settling basins to provide for removal of silt before it reaches

the stream or lake. Special requirements may be made by regulatory agencies for each stream system to protect spawning beds.

3. Installation of culverts on streams classified as a fishery resource should be at low gradient with the bottom of the outlet below the natural streambed to prevent erosion at the downstream end of the culvert.

4. When necessary, because of outfall erosion, an approved stilling basin should be constructed at the downstream end of the culvert. Stabilize the pool sides with riprap or other appropriate material to prevent erosion.

5. Water may be diverted around the work area in the streambed during the installation of the culvert to reduce sedimentation. To avoid erosion, a conduit may be needed.

6. Water diversion ditches or pumps should be screened with an approved device to prevent harm to migrating fish.

7. Abandoned water diversion structures should be removed, if at all possible, or be plugged and stabilized to prevent trapping fish or impeding fish passage.

8. Construct erosion control measures, such as water bars, contour furrows, water spreaders, diversion ditches, or plugs, to avoid induced and accelerated erosion and to lessen the possibility of forming new drainage channels resulting from construction activity on all right-of-ways areas. Control measures must be designed and constructed to minimize disturbance to the thermal equilibrium, thus reducing the adverse effects of permafrost degradation.

9. Unless otherwise approved, temporary access over stream beds should be made through use of fill ramps, made of coarse materials, rather than by

excavating through stream banks. Such ramps should be removed upon termination of seasonal use or abandonment.

10. Give special attention to stream and river crossings to prevent erosion. Such measures should not interfere with fish passage.

Support Activities

1. The contractor should assure that all persons take appropriate measures for the prevention and suppression of fires on the right-of-way area and on other lands, and comply with all applicable laws and regulations, and with instructions and directions concerning the prevention and suppression of fires.

2. Do not attempt area-wide pest control; such action frequently leads to ecological unbalance. Pesticides and herbicides are limited to nonpersistent (such as parathion, malathion, or pyrethrum, to name a few) and immobile types. When pesticides are used, only those from an approved list may be applied.

3. Camp wastes of all kinds will be disposed of by acceptable methods designated by State sanitarians. Effluents from treatment systems shall not pollute receiving waters.

4. No petroleum wastes will be either disposed of to the environment or allowed to enter any body of water; these wastes include oil changes, spilled fuel, and antifreeze.

5. Keep mobile ground equipment out of all water courses except for crossings within the right-of-way limits, and then only in a manner so as to eliminate or minimize disturbance.

6. Do not operate vehicles outside the boundaries of the right-of way, previous access or other roads, or other permitted areas, except with permission, or when necessary to protect life, limb or public property.

Restoration:

1. Leave all slopes in a stable condition.

2. Level haul ramps, berms, dikes and other earthen structures unless otherwise directed.

3. Connect material pits in stream and river bottoms and channels to the stream by channels constructed to allow flow of water through the pit at median stream stage.

4. Vegetation, overburden and other materials removed from surfaces of material sites should be disposed of at termination of use of the site in an approved manner. Spread chipped vegetative debris evenly over material site slopes, together with other organic materials and topsoil. If possible, during construction or immediately following terminal use of the site, revegetate material site slopes through seeding and planting with suitable plant materials unless otherwise directed. Seeding in the snow is one procedure that should be considered and used if feasible to take advantage of early moisture for seed germination.

5. Upon abandonment or relocation of a campsite, the area should be cleaned up and restored to a condition satisfactory to the regulatory agency.

6. Leave all disturbed areas in a stabilized condition. Stabilization practices may include: seeding, planting, mulching, and the placement of mat binders, soil binders, rock or gravel blankets, or structures, as

determined by the conditions of the site. (Figures 38 - 42 illustrate several unstable conditions that resulted in preventable erosion.)

7. Seeding and planting should be conducted as early as possible during the first growing season and repeated if unsuccessful on the first attempt. All other restoration should be completed as soon as possible following the completion of the project. (See B.P.R. Instructional Memorandum No. 20-3-70, Appendix, and Figures 43 and 37.)

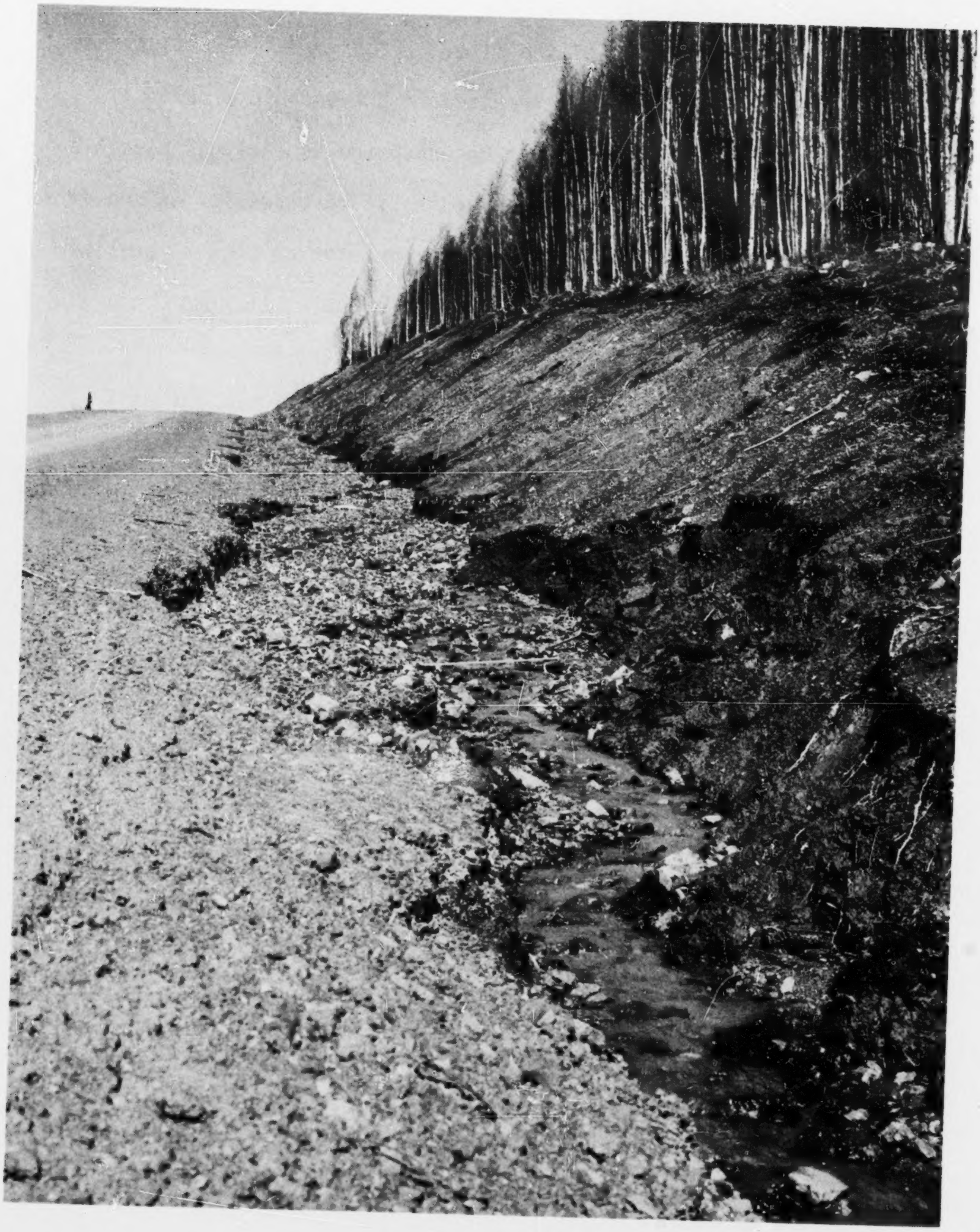

Figure 38. Erosion of a roadside ditch during heavy rain. No diversion or drain structure was installed along this stretch of road.

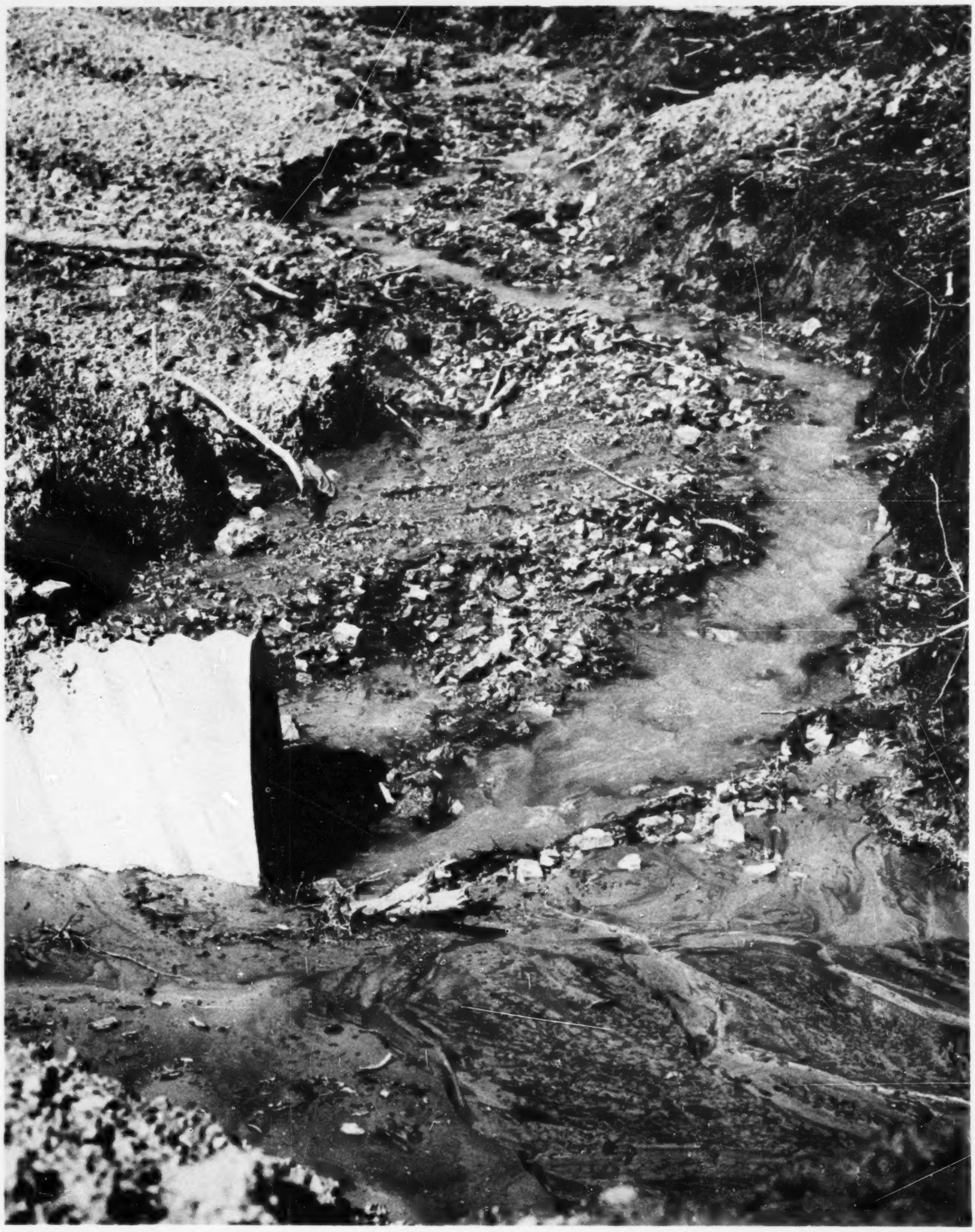

Figure 39. The only culvert draining the ditch shown in Figure 38; it is half filled with sediment. Such design will increase maintenance costs over many years. May 26, 1970.

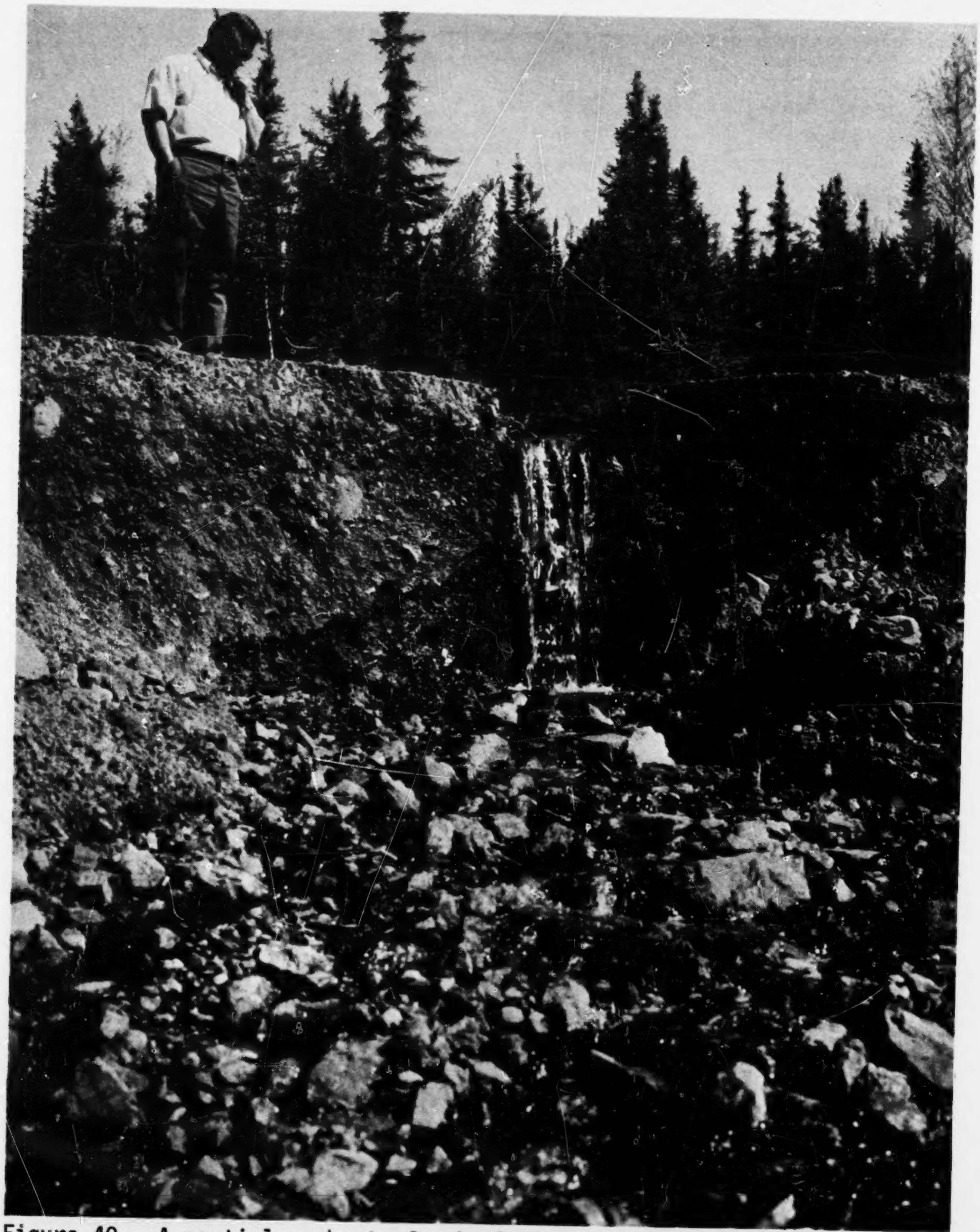

Figure 40. A partial washout of a haul road because proper drainage was not provided. Although this erosion did not endanger the road, it did cause a heavy load of sediment to enter the stream system as preventable pollution. May 26, 1970.

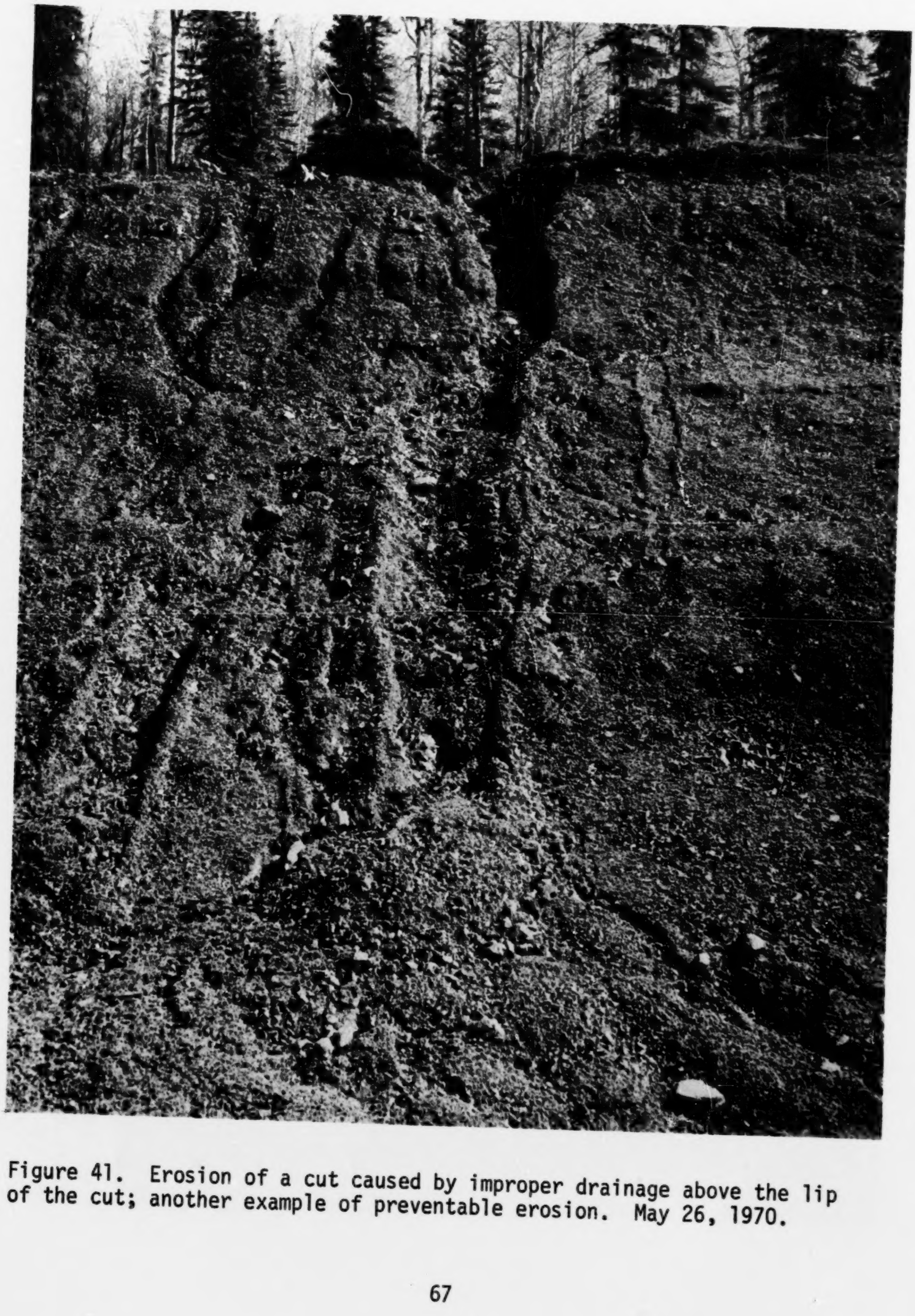

Figure 41. Erosion of a cut caused by improper drainage above the lip of the cut; another example of preventable erosion. May 26, 1970.

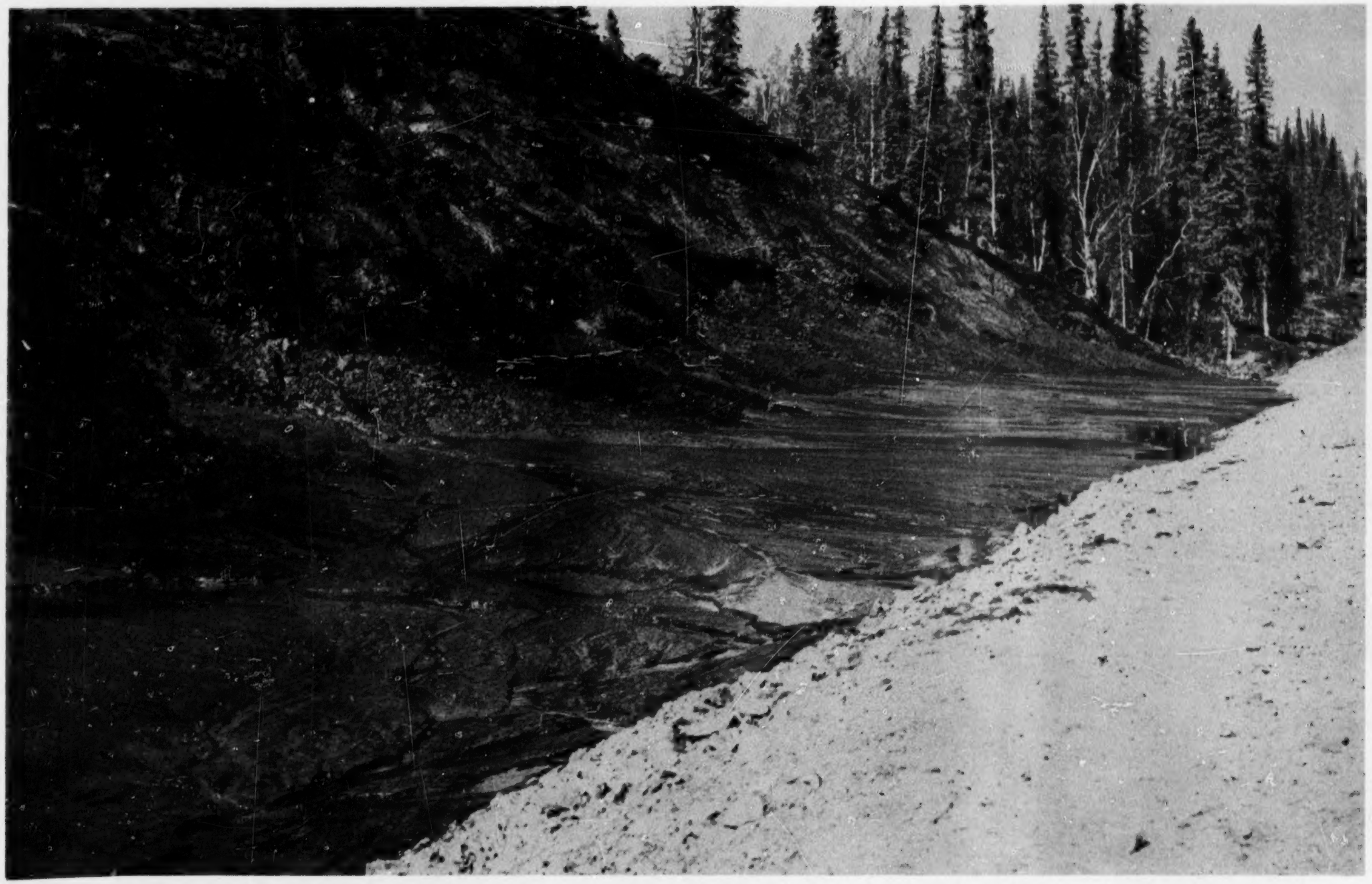

Figure 42. Silt accumulation along the road from melting ice of a sloped cut. Some of this silt released by thawing ends up in the small streams and acts as a pollutant. This is an example of rapid thawing with consequent pollution from silt; note absence of vegetal mat, characteristic of sloped cuts. May 26, 1970.

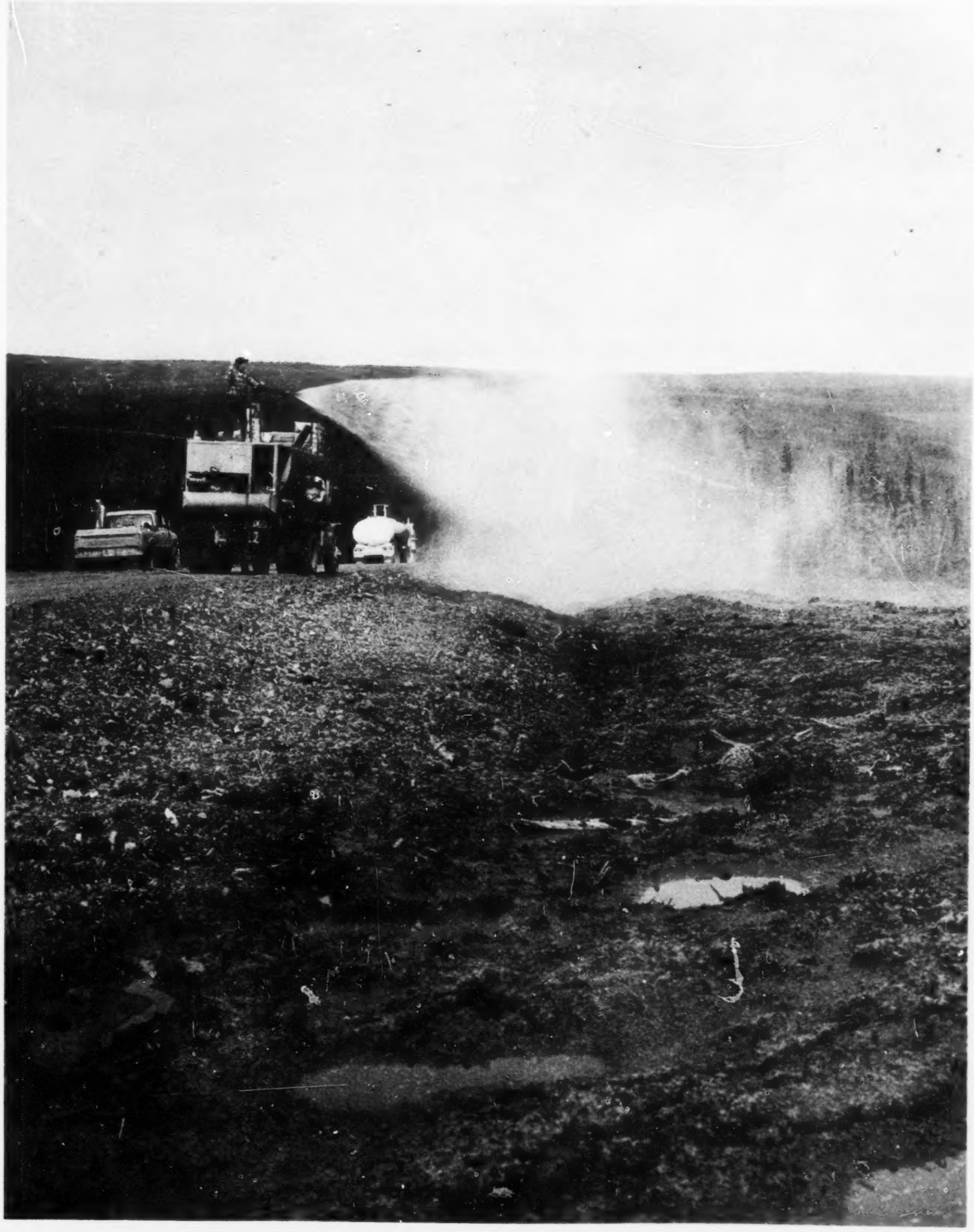

Figure 43. Timely seeding of raw cuts and fills by mixture of seeds, fertilizer, matting or mulching material, and irrigation water results in the scene shown in Figure 37.

SECTION V

MAINTENANCE

Proper maintenance is a key activity if any road is to remain usable. Long after construction activity ceases, maintenance must continue in an efficient and timely manner if a road is to satisfy the need. Maintenance must continue as long as a road is being used and its accrued cost may equal or exceed the original cost of construction. These costs can be reduced if the route is properly selected and the problem areas are properly handled during design.

Permafrost and long, severe winters cause some unusual problems in Alaska that add to those of road maintenance encountered in milder climates. In coastal areas, heavy rainfall causes erosion. Seepage zones in Interior Alaska cause icings that may build up to several feet if steps are not taken to keep small channels thawed to remove liquid water and prevent its freezing on the road surface. Small streams also add to maintenance problems caused by icings. The locations of icings are not easily predicted, but are related to past and current seasonal distribution of precipitation and other unknown factors. At some points icings can usually be expected but the severity may have a wide range from year to year. Unless icings are controlled, extremely hazardous driving conditions result from the buildup of ice on the road. (Figures 44 - 49)

Another maintenance problem associated with long cold winters is that of "frost boils" that appear during the spring breakup. These, like icings, are unpredictable in location and are usually random in distribution.

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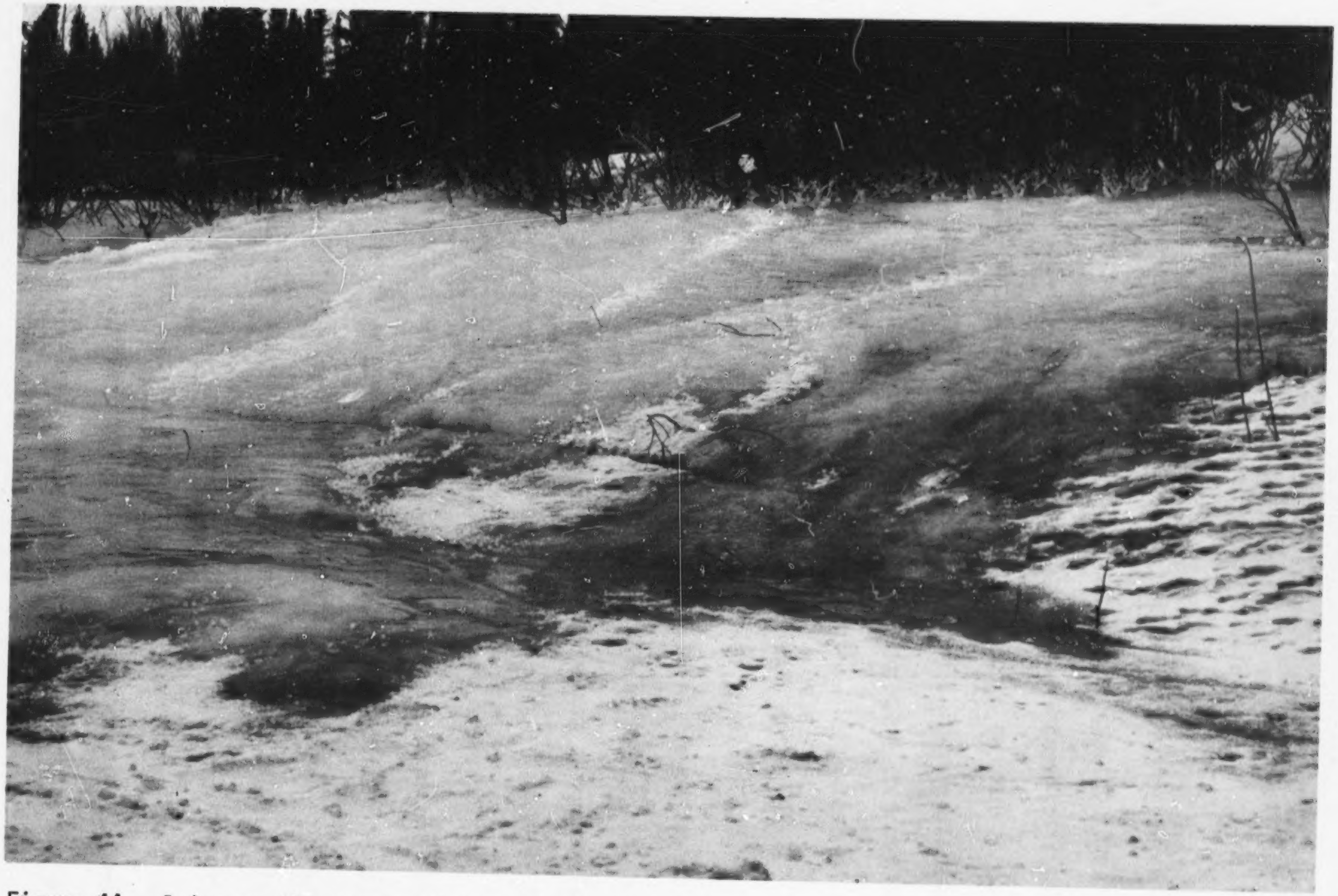

Figure 44. Icing on the Steese Highway about 60 miles northeast of Fairbanks. This illustrates the appearance of a typical icing and gives an idea how they are formed by surface increments of ice as water flows over the ice and freezes in the cold air.

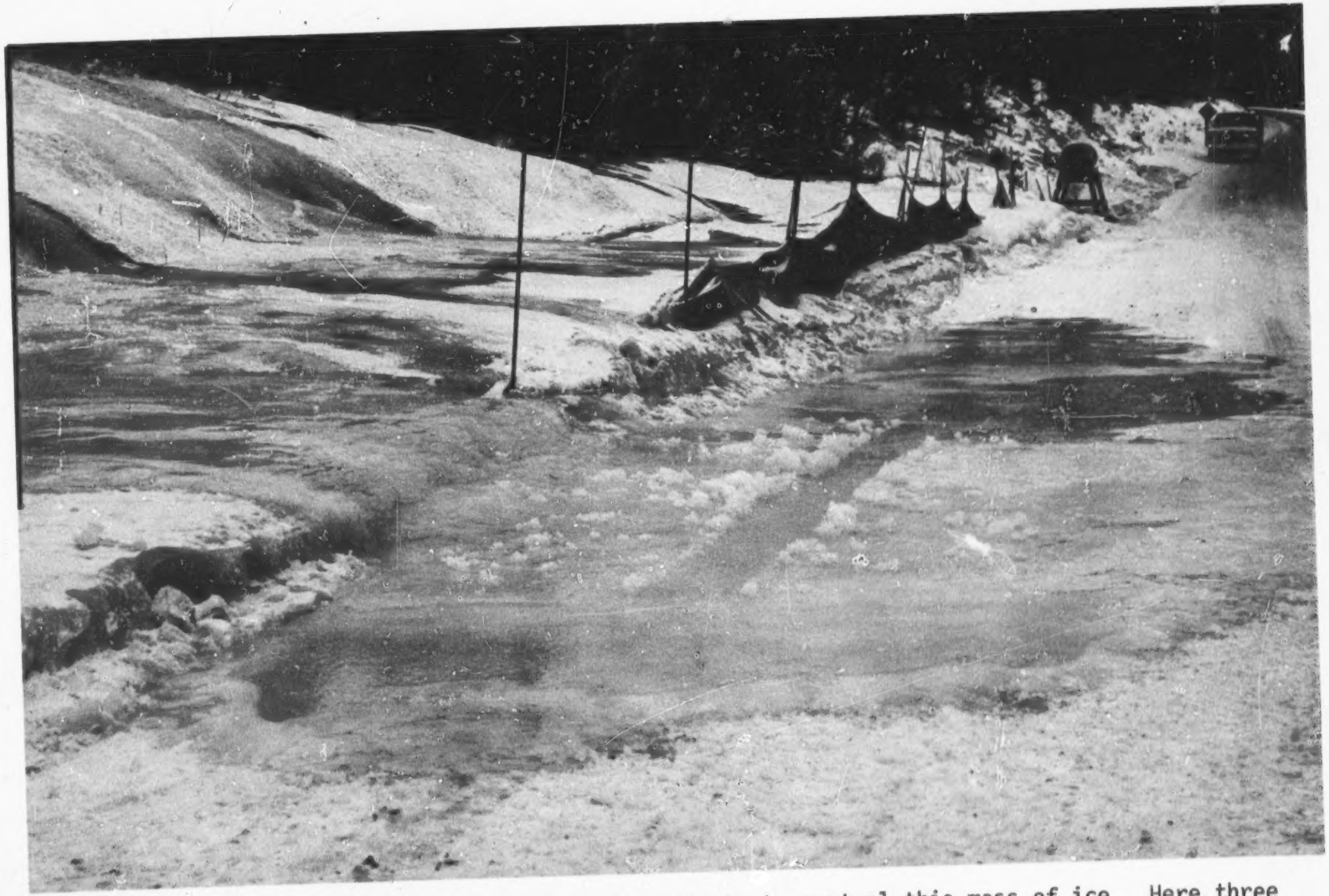

Figure 45. View of an icing showing maintenance efforts to control this mass of ice. Here three methods are shown: a hessian cloth dam, a fire pot to thaw a narrow channel, and sheer power by ripping and grading.

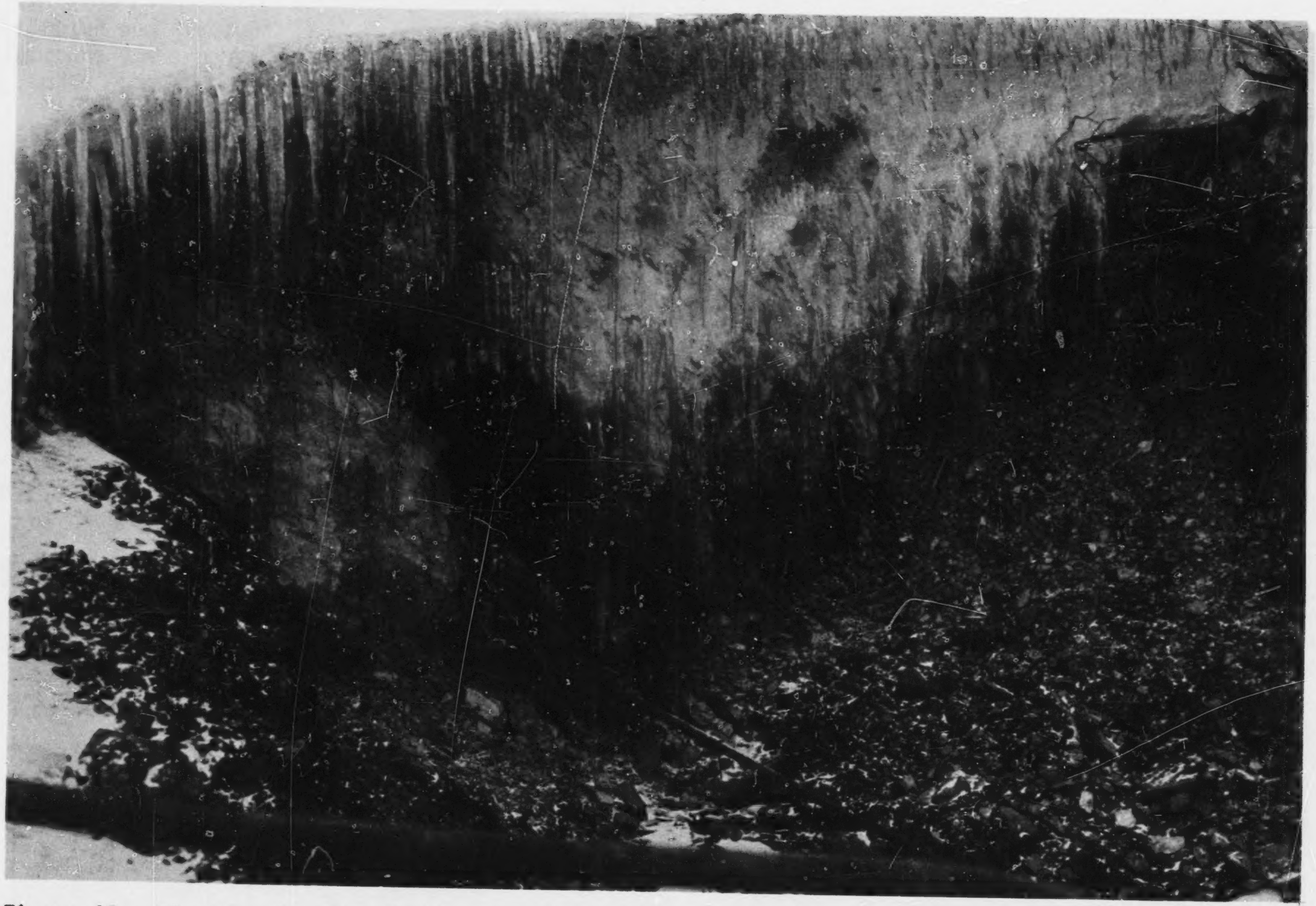

Figure 46. Closeup of a thawed channel using a fire pot. Once a narrow channel is opened, running water tends to keep it open with a small amount of heat.

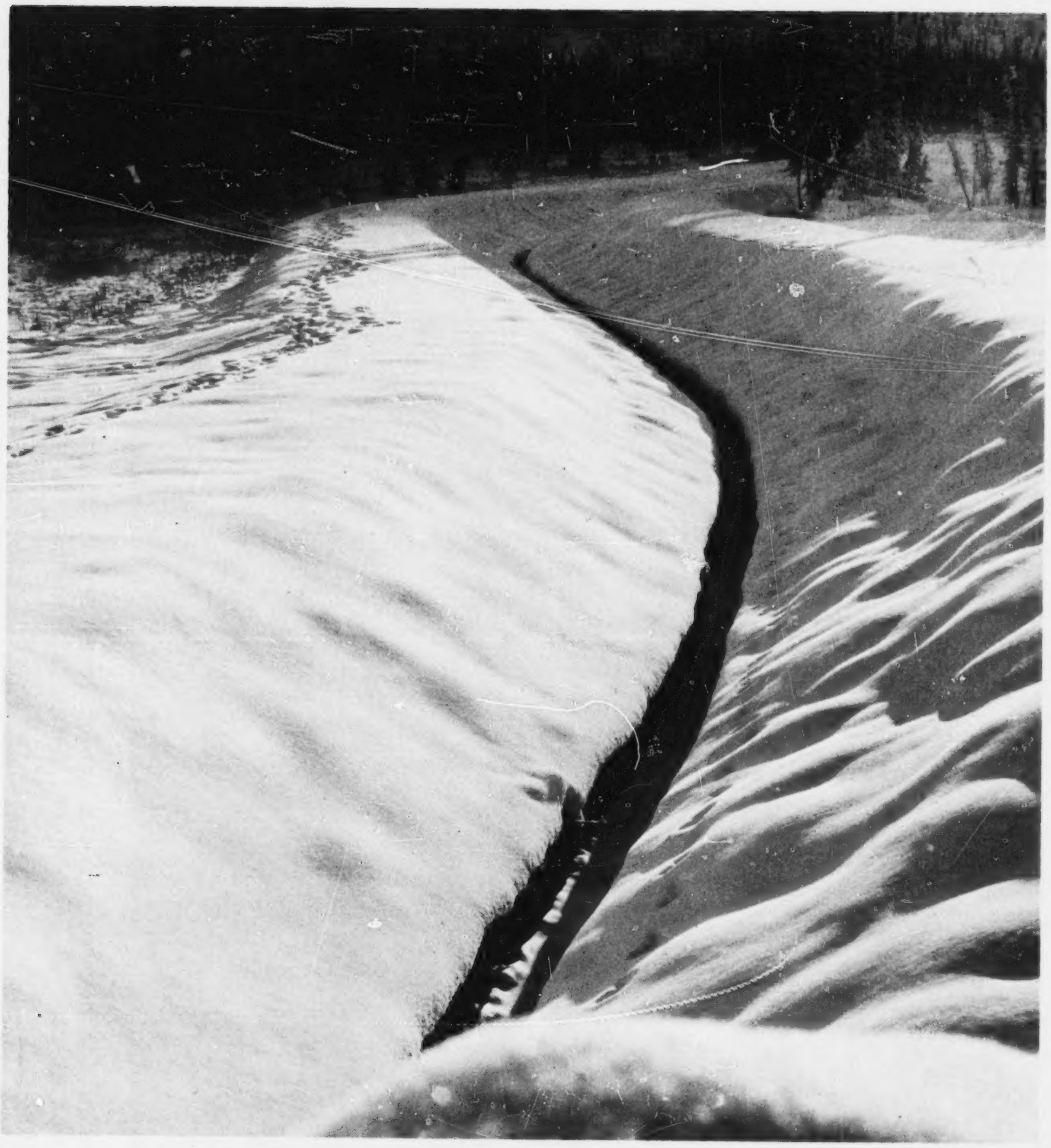

Figure 47. This photo shown an alternate method to control icings using rock gabions. A narrow, deep water course replaces the original stream and offers a good engineering solution to icings in this stream. However, from a sport fishery point of view, it has ruined the stream which was formerly a good grayling stream. Velocity of this artificial stream is too high to allow fish to ascend to spawn; moreover, no places to hide are provided which are needed by many fish. This illustates how one solution to a problem may have side effects not considered by those making the decision to control the problem; the results are obvious to any fishery biologist.

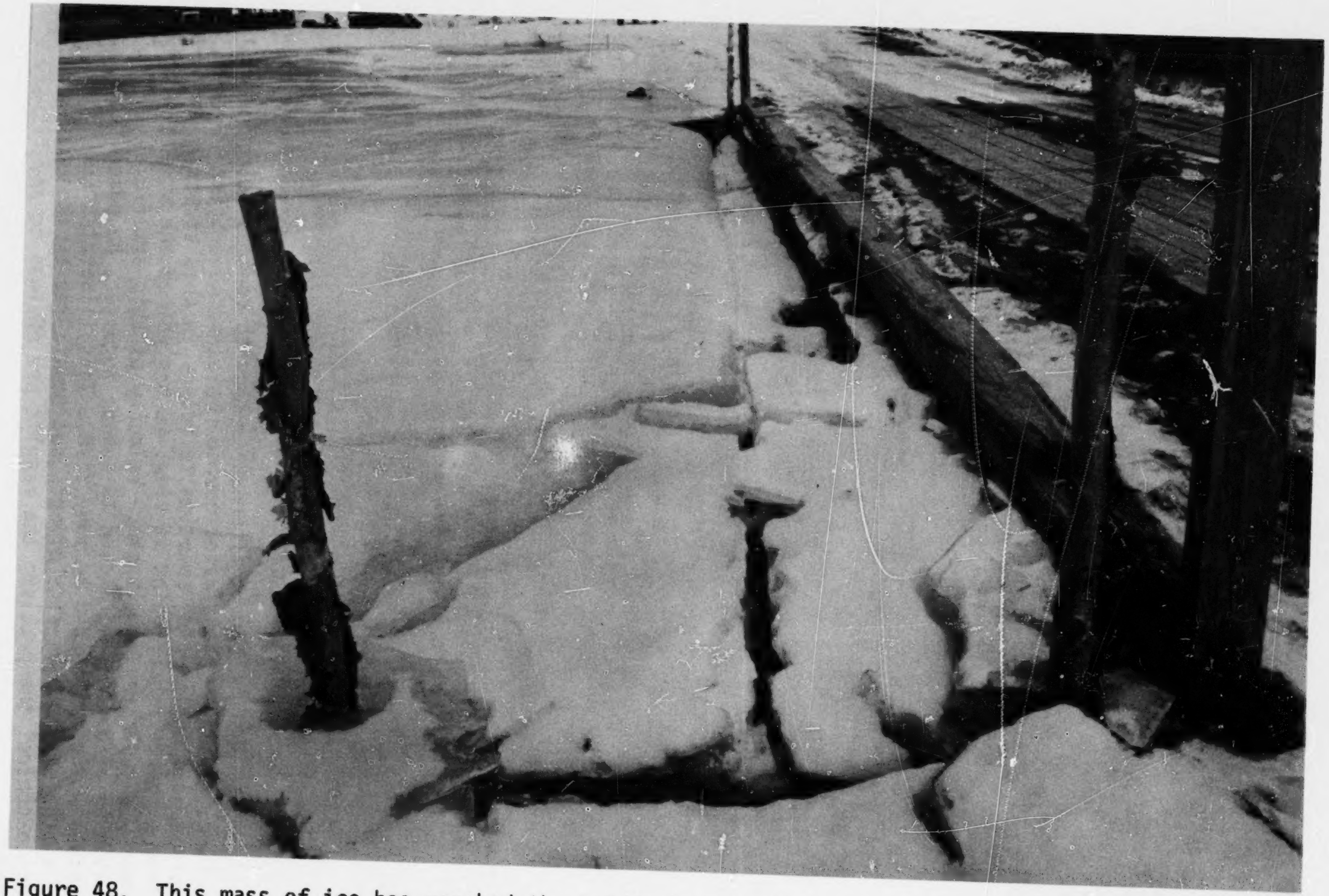

Figure 48. This mass of ice has reached the bridge level and is several hundred feet across and 6-8 feet thick. No attempt at control was evident here; this highway is usually closed during the winter. Mile 46 Steese Highway.

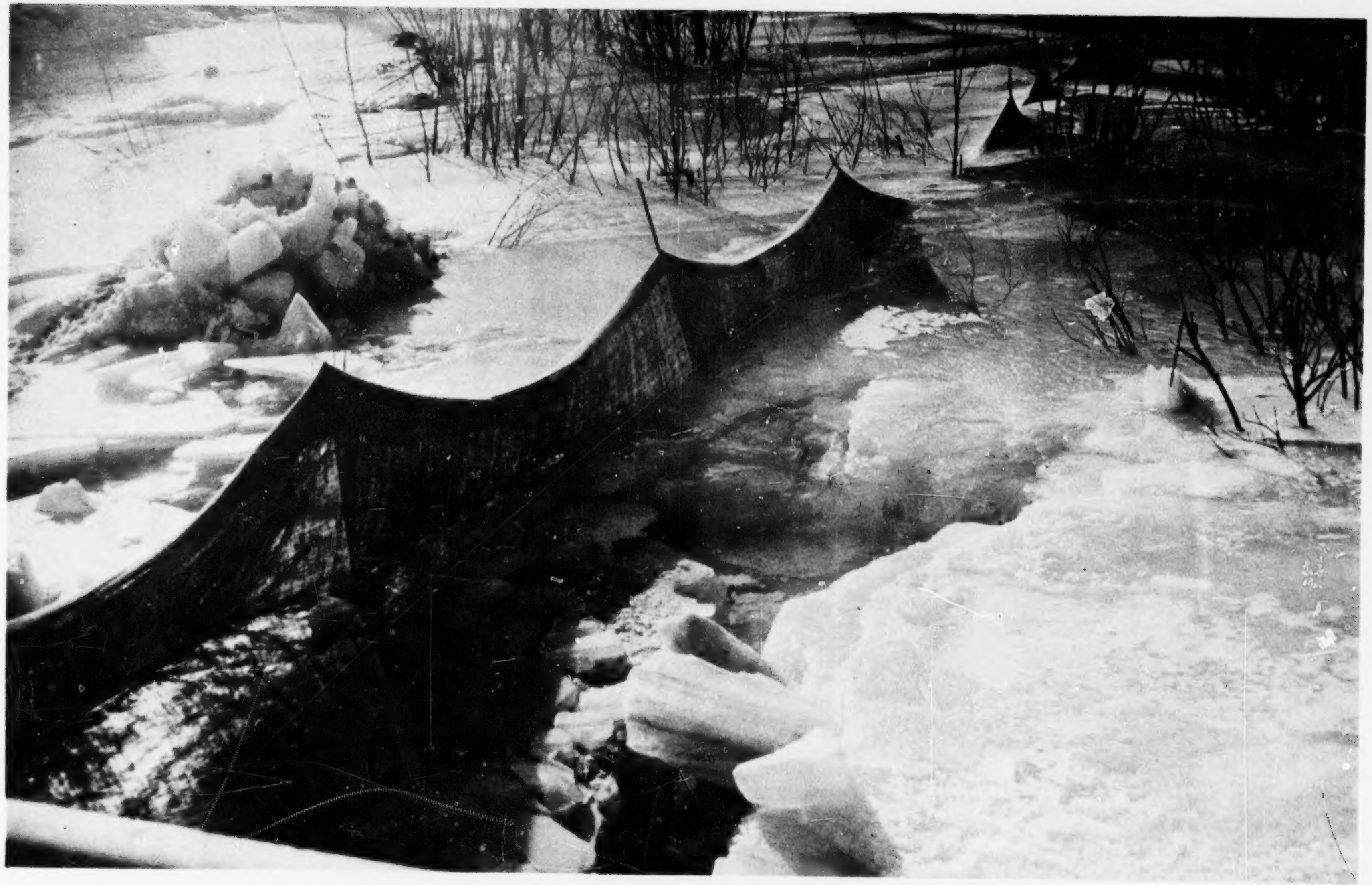

Figure 49. Closeup of hessian cloth dam. Burlap stretched between posts absorbs liquid water which rises a short distance before freezing and acts as a dam. They are effective with small volumes but are overwhelmed by moderate flows as is shown here in March 1970; flow is to the left. Creek flowing by Fox Spring. (near Fairbanks)

Good design can reduce the incidence of these boils and route selection can avoid areas that have conditions likely to cause them to appear. Frost boils are the result of improper design and construction and are caused by excess water directly beneath the roadsurface. Traffic pumps the subgrade causing it to lose its bearing capacity resulting in chuck holes.

Stabilizing cut and fill banks poses a serious problem where silty or other unstable materials must be used. Unless such materials are stabilized, erosion can cause stream pollution and sometimes fill culverts to the extent that they become plugged and perhaps cause a washout. Silty materials in borrow ditches must be protected from erosion where the road is on an incline or gullies will form along the road. Moreover, the eroded material flows to the nearest drainage and causes problems by filling stream channels and culverts. (Figures 24 and 39)

Maintenance of major roads and highways normally is on a timely schedule and is on a continuing basis. Minor and pioneer roads suffer from neglect and frequently cause local sedimentation because maintenance is sporadic or has such a low priority that damage occurs between widely scheduled repairs.

Guidelines for Maintenance:

1. Plan and schedule maintenance on a continuous basis for routine work.

2. Alert all personnel to report any unusual maintenance need, such as a new frost boil or sedimented culvert, before it becomes a serious problem.

3. Keep all cuts and fills that are subject to erosion covered with vegetation or some other material for stabilizing such susceptible areas.

4. Use fertilizers and chemical stabilizers where natural fertility is low to give vegetation a chance to make more rapid growth. Use chemical dust control on unpaved roads to lessen the hazard of driving and passing on dusty roads.

5. Do not disturb stabilized slopes with maintenance equipment.

6. Keep the road crowned and free of ridges along the edge to maintain lateral drainage.

7. Do not move material cleared from ditches to where it can wash into water courses.

8. Allow loessal soils to come to stability by letting the slopes become nearly vertical; this is the most stable slope for these materials. Under such conditions, drainage must be provided and maintained to prevent water from running over the upper edge of the cut bank.

9. Take early, active measures to control icings on highways designated as all year routes.

SECTION VI

PROBLEMS OF THE TRUE ARCTIC

In Alaska the true Arctic exists north of the Brooks Range while the Subarctic extends throughout the Interior. Permafrost is deep, continuous, and colder than in areas of discontinuous permafrost, and ice wedges are actively forming. Seasons for vegetal production are only about two months long and trees are entirely absent except for low growing willows. These conditions pose unique problems to construction that must be solved in unconventional ways if extensive damage to other resources is to be prevented during resource development.

Using permafrost to advantage is proving practical as engineers and operators learn and use procedures for construction that utilize frozen soils as foundations. Recent experience in the Arctic has established the feasibility of constructing permanent engineering works if proper attention is given to environmental considerations. Large structures can use passive measures to preserve permafrost (Muller, 1947) and drilling rigs and roads use gravel of sufficient thickness to use permafrost as foundations. Both procedures are satisfactory if properly done. The Environmental Atlas of Alaska (see references) prepared by Johnson and Hartman gives valuable data for regional planning.

Recent successes on the Arctic Slope illustrate that it is desirable and feasible to preserve and use the local environment during industrial development. Some of the earlier attempts at road building, movement of heavy equipment, and drilling pads resulted in glaring failures because

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insufficient forethought was given to the problem at hand. (Figures 50 - 53.)

Proper drainage procedures are of utmost importance on the tundra and seem to contradict usual engineering practices. When the active layer melts and is drained away as water, a large volume of active layer is removed because of the very high ice content. Under these conditions it becomes mandatory to prevent drainage of the thawed active layer and allow the water to stand and freeze when cold weather returns. On the other hand, because of frozen subsoils and a saturated active layer when thawed, any small rain causes extensive runoff which accumulates behind the elevated roads unless proper cross-drainage is provided. Thus, the proper siting of cross-drainage structures and the establishment of invert elevations to control runoff and at the same time conserve the active layer is one of the most important engineering functions of road design and construction in the Arctic. Earlier failures, as illustrated in Figures 51 and 53 prompted much of the criticism of environmentalists who are interested in preventing unnecessary damage during resource development.

Despite successes with gravel as an aid in preserving permafrost, better methods are needed. Experiments underway indicate that artificial insulating materials will reduce the volumes of gravel needed while maintaining permafrost stability. Hugh volumes of gravel are now being used which is costly because of hauling distances and limited supplies (Condo and Knight, 1970). The studies referred to may result in insulating techniques which will allow up to 70 percent reduction of the volume of gravel used, thereby reducing damage to the environment and lowering construction costs.

River beds will not have to be mined for gravel to the present extent and problems with drifting snow should be less with gravel fills of two or three feet instead of the five feet now being recommended.

Guidelines for Arctic Alaska:

1. When building roads do not disturb the tundra, place gravel or other insulating material directly on undisturbed vegetation. Experience has shown that this method will minimize melting under and along the road. (Compare Figure 50 with Figures 51 and 52 with 53.)

2. Where melting has occurred do not drain away the water. Let it remain in the meltpond to freeze when cold weather returns. Because of very high ice content of tundra soils, removal of meltwater effectively causes loss of large volumes of surface soil. Subsequent seasonal melting then causes more soil removal which continues the cycle.

3. On flat tundra install sufficient drains under elevated roads to carry runoff from summer showers, otherwise this water ponds up on the upper side and can cause melting or washouts. The tundra slopes gently to the north and even small showers can result in large runoff because of the frozen subsoil and saturated soils.

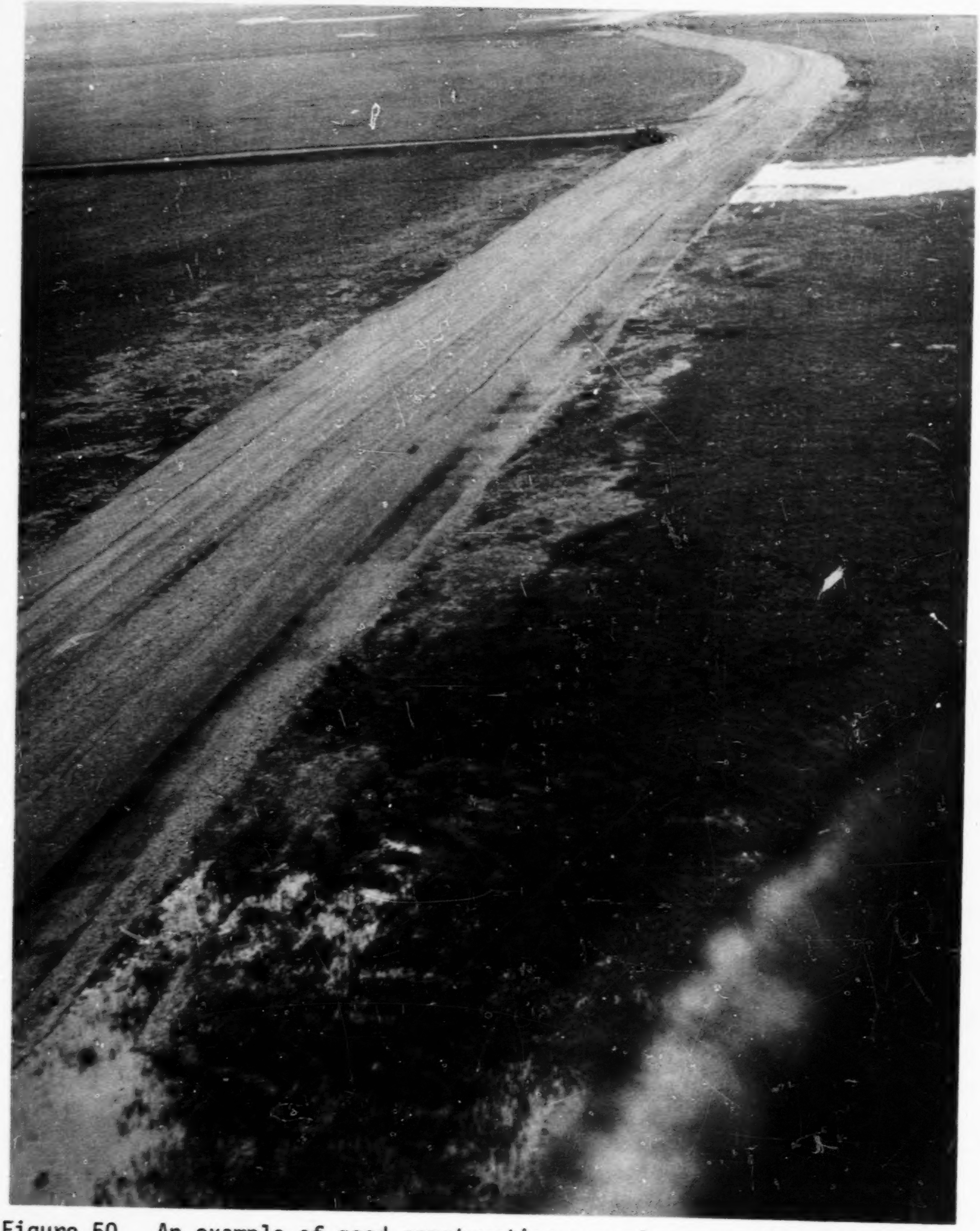

Figure 50. An example of good construction procedures on the arctic tundra. Note the absence of disturbance on the road margins and few tracks on the adjacent tundra; west of Put River, arctic Alaska, July 21, 1970.

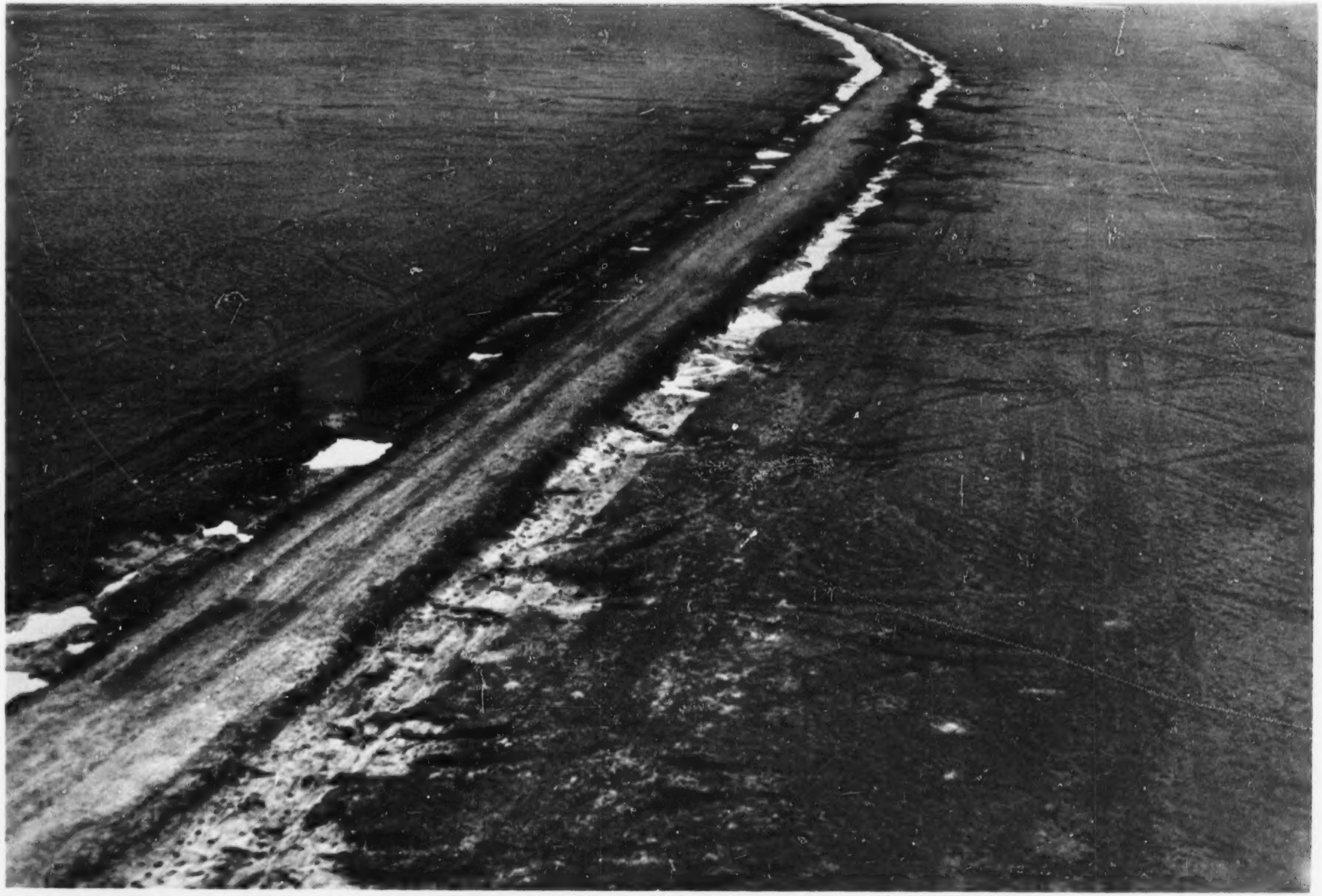

Figure 51. An example of unsatisfactory road construction with melting borrow ditches and numerous tracks from traffic on the tundra.

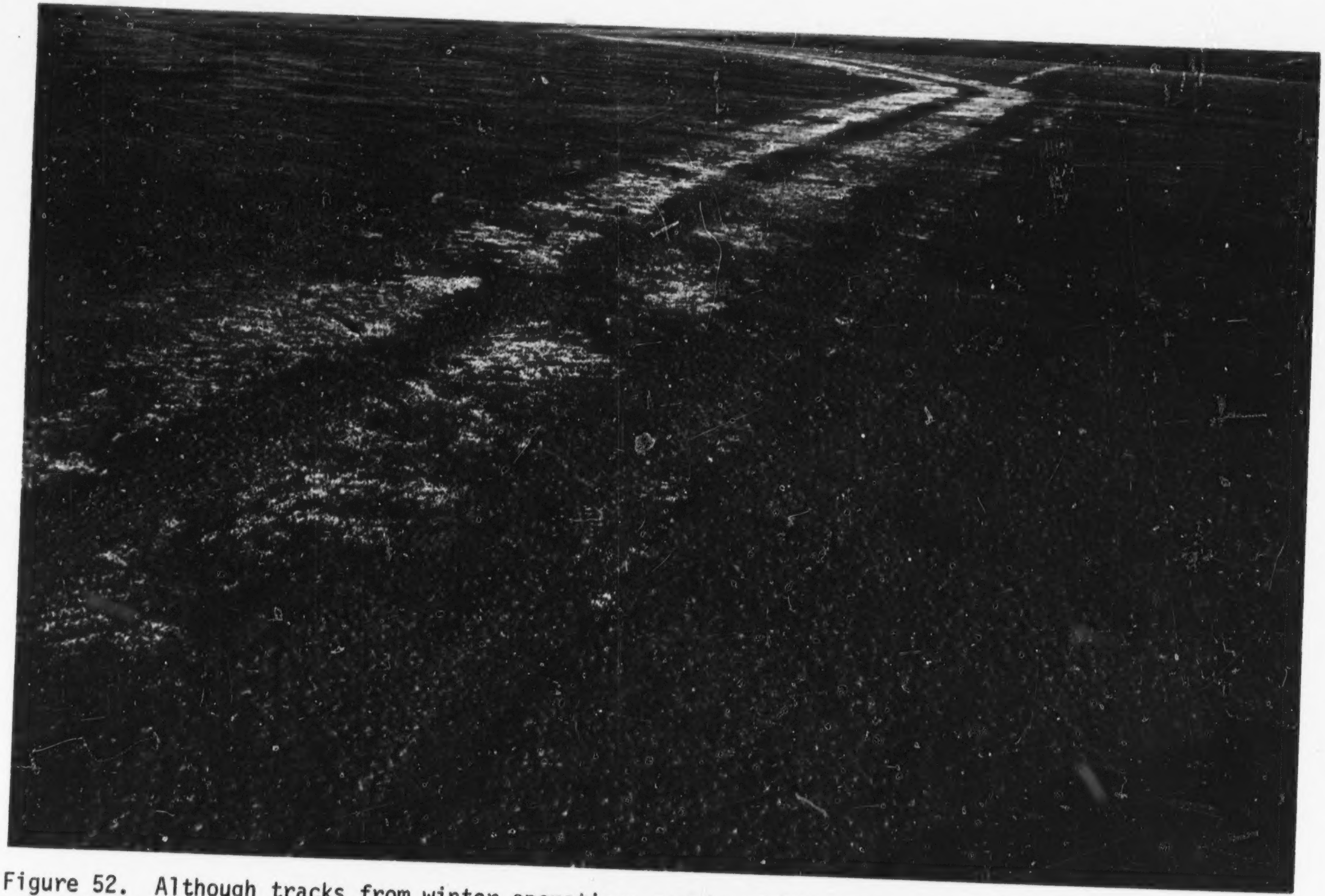

Figure 52. Although tracks from winter operations remain visible for years, they are not necessarily unstable if the tundra is not removed. This is a view of old tracks north of Sagwon, arctic Alaska; all of these tracks are now green. July 21, 1970.

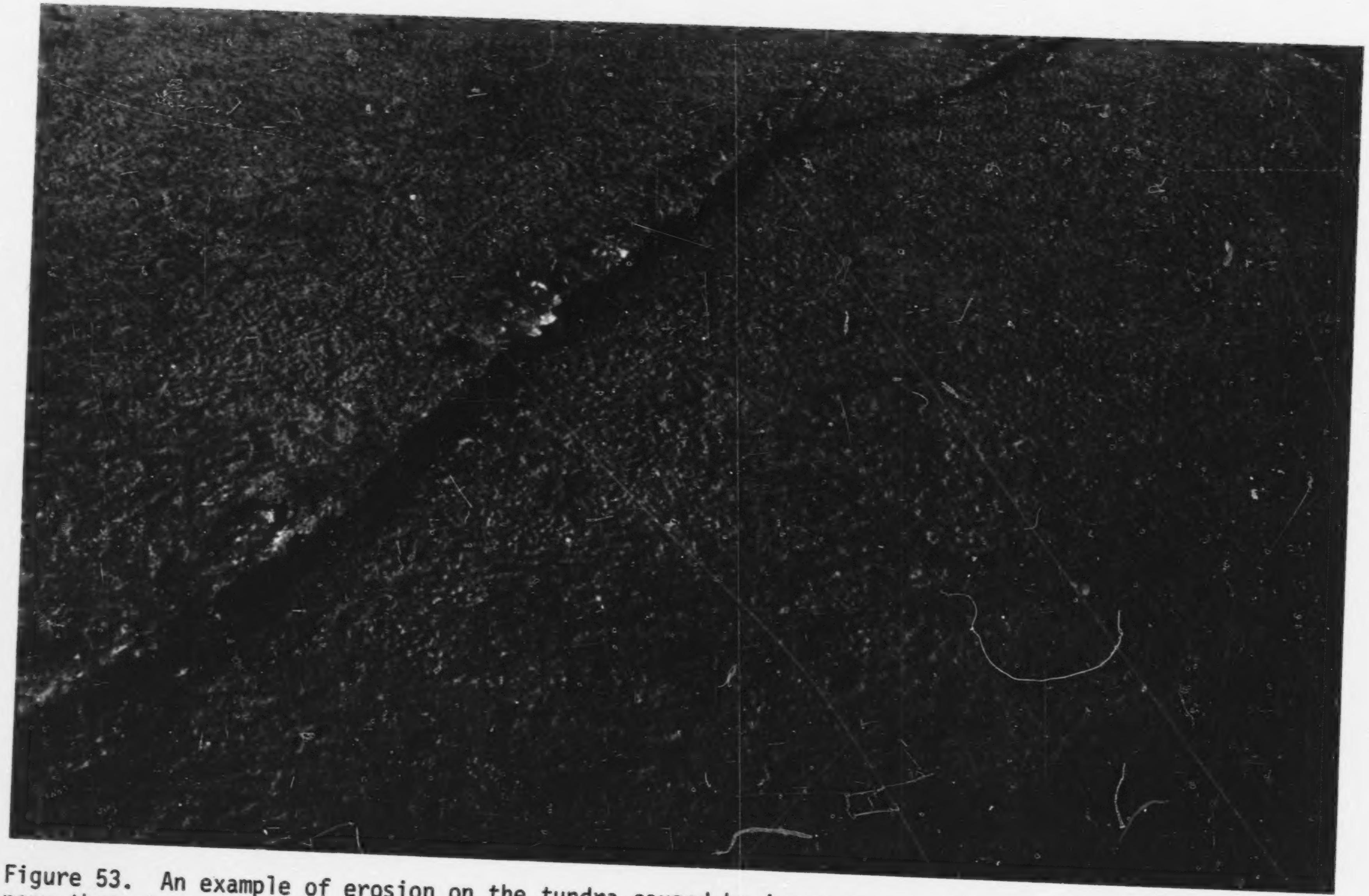

Figure 53. An example of erosion on the tundra caused by improper use of equipment. The scene is near that shown in Figure 52, hence, is in similar terrain; the significant difference is the care taken to prevent damage in the case shown in Figure 52 and absence of proper care in the example shown here. July 21, 1970.

SECTION VII

ACKNOWLEDGEMENTS

This guide has drawn information from many sources and we wish to acknowledge the assistance of the agencies that willingly shared their time and knowledge: Bureau of Land Management, Department of the Interior; State Highway Department, State of Alaska; Alyeska Pipeline Service Company; Department of Civil Engineering, University of Alaska; Bureau of Public Roads, U.S. Department of Transportation.

We are grateful for the contributions of the several persons from outside the Alaska Water Laboratory who reviewed this guide. Many of our statements in earlier drafts were revised on the basis of their suggestions.

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SECTION VIII

ADDITIONAL CITED REFERENCES

Some of these references are cited in the text; most of them are listed here to aid interested readers who desire to learn more about some of the problems and procedures of road building in northern climates:

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SECTION IX

GLOSSARY

Active layer: the upper layer of permafrost that undergoes an annual freeze-thaw cycle.

Aquatic ecosystem: the life system of any body of water. It includes all forms of life living in or associated with the water, the water itself, and all physical factors affecting life in the water. Such a system is in dynamic equilibrium, sometimes a tenuous equilibrium, and all parts are interrelated so that slight changes in any one may affect the entire system. For such a system to remain viable, major portions must fulfill their roles, from primary producers to the intermediate parts of the food web, to the highest predator, to decomposers which make most of the energy and nutrients available for recycling. Such an undisturbed system can continue its various life cycles without interruptions because it has evolved over time to make use of resources available to it under the physical constraints of its total environment.

Damage: as used in this guide, some effect of man's activities that is deleterious to life in a body of water or that lowers water quality. In construction activities it usually takes the form of disturbing spawning grounds by equipment in stream bottoms, sedimentation by silt and clay on gravels which exclude oxygen, high turbidity which lowers light penetration to reduce productivity, and accidental or intentional spilling of petroleum products or other wastes into streams. Some of these

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effects are slight, some temporary, and some serious and of long duration; however, most, if not all, are preventable if positive steps are taken to prevent such damage by using recommended procedures during the construction process. Adverse effect on aquatic life is any effect that interferes with the normal functioning of an aquatic ecosystem. Damage, such as that described above, can result from natural processes, floods, tidal waves, earthquakes, or fires as examples. These are usually not of a persistent, recurring nature and must be accepted as part of the dynamic evolution of landscapes and life in the earth ecosystem.

Fish spawning beds: the bottom areas in a stream or lake where fish deposit their eggs.

Glacial stream: a stream draining a glacial valley, and includes melt water from the ice mass with its finely ground particles to give a highly turbid water. These small particles arise from the grinding action of the moving ice on bedrock and cease to be produced if the ice is stationary. Many glacial streams are clear in winter because freezing immobilizes meltwater. As an example, Tanana River runs clear most of the year under the ice although it is extremely turbid in summer when glaciers are active and large quantities of meltwater are produced.

Loessial soil: soil developed from wind-deposited, fine-grained material (silt and finer).

Patterned ground: polygons, visible as surface features, that result from repeated cycles of freezing and thawing of surface material.

Permafrost: permanently frozen ground:

(a) Continuous: areas of deep frozen ground (up to 1200 feet thick) whose temperature at depth of zero amplitude (where temperature shows no annual fluctuation) is less than 5°C below freezing.

(b) Discontinuous: areas of permafrost where the temperature at depth of zero amplitude ranges from 0.5°C to about 4°C below freezing.

Pollution: the process of adding man's generated wastes to any water body in sufficient quantities to have a deleterious effect on organisms living in or depending on the water. Eroded materials, arising from road building, that are deposited in streams, are thus classified as pollutants as are similar materials from mining or gravel washing operations. Pollution is not restricted to organic contamination (bacteria and sewage, as examples), but includes all wastes from man's activities that, upon entering any water, has an adverse effect on the biology of the water and interferes with other beneficial uses of that water.

Restoration: making the raw scars of construction blend in with the original landscape. Public pressure for restoring evidence of construction is becoming apparent because it is now realized that everyday activities are more enjoyable in a natural environment and costs for such work should be part of the construction contract. Moreover, it has also been shown that, if the initial plan includes restoration, costs of restoration are much smaller than if delayed. In addition, prompt restoration helps to increase the esthetic appeal of a well-designed engineering work and makes the costs more acceptable, stabilizes raw soil, and what is all important, minimizes the impairment of the total environment.

Sedimentation: as defined by Webster, the action or process of depositing sediment; and so it will be used in this report. (Sediment is: (1) the matter that settles to the bottom of a liquid, and (2) material deposited by water, wind, or glaciers.) Silt, used as a verb, has the connotation of sedimentation or the process; silt, as a noun, is the fine material carried by water or wind; siltation is the process of depositing silt-sized particles in water. The overall process of depositing all particle sizes is sedimentation and does not have the bias of size specification; this term is the preferred one and is used throughout this guide. Where clarification of meaning is needed, when dealing with specific sizes, it is provided during that discussion.

Toxic substances: similar in meaning to poisons; substances which may have serious adverse effects. Some examples are copper, mercury, lead, and pesticides, all of which have deleterious effects or are lethal to most life when present above certain limits.

Tundra: the layer of live and decomposed plant material over continous permafrost, usually restricted to the treeless regions of the Arctic.

Turbidity: suspended particulate material in a body of water. The main objections to turbidity are its appearance, the exclusion of light for photosynthesis, and the physical effect of particles on stream organisms.

SECTION X

APPENDIX

This appendix is arranged in the present order to demonstrate several events: (1) the national concern with environment as evidenced by P.L. 91-190, National Environmental Policy Act of 1969; (2) prompt implementation of provisions of the act evidenced by Executive Order 11514; and (3) a series of Instructional Memorandums by the U.S. Department of Transportation dealing with highway construction in response to this Executive Order. The various sections of the appendix serve to illustrate how and why this guide was prepared; to bring to the attention of all persons concerned with road building that its provisions and recommendations result from a national concern with the need for protecting our entire environment. This particular guide is to be applied to Alaskan conditions and will be made available to the general public, State and Federal agencies, public representatives, and especially to those who are directly involved with road building: engineers, contractors, and equipment operators.

Public Law 91-190
91st Congress, S. 1075
January 1, 1970

AN ACT

To establish a national policy for the environment, to provide for the establishment of a Council on Environmental Quality, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Environmental Policy Act of 1969".

PURPOSE

SEC. 2. The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation, and to establish a Council on Environmental Quality.

TITLE I

DECLARATION OF NATIONAL ENVIRONMENTAL POLICY

SEC. 101. (a) The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances and recognizing further the critical importance of restoring and maintaining environmental quality to the overall welfare and development of man, declares that it is the continuing policy of the Federal Government, in cooperation with State and local governments, and other concerned public and private organizations, to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.

(b) In order to carry out the policy set forth in this Act, it is the continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may--

(1) fulfill the responsibilities of each generation as trustee of the environment for succeeding generations:

(2) assure for all Americans safe, healthful, productive, and esthetically and culturally pleasing surroundings;

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(3) attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;

(4) preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity and variety of individual choice;

(5) achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and

(6) enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

(c) The Congress recognizes that each person should enjoy a healthful environment and that each person has a responsibility to contribute to the preservation and enhancement of the environment.

SEC. 102. The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this Act, and (2) all agencies of the Federal Government shall--

(A) utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment;

(B) identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by title II of this Act, which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations;

(C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on--

(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action,

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate Federal, State, and local agencies, which are authorized to develop and enforce environmental standards, shall be made available to the President, the Council on Environmental Quality and to the public as provided by section 552 of title 5. United States Code, and shall accompany the proposal through the existing agency review processes;

(D) study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources;

(E) recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment;

(F) make available to States, counties, municipalities, institutions, and individuals, advice and information useful in restoring, maintaining, and enhancing the quality of the environment;

(G) initiate and utilize ecological information in the planning and development of resource-oriented projects; and

(H) assist the Council on Environmental Quality established by title II of this Act.

SEC. 103. All agencies of the Federal Government shall review their present statutory authority, administrative regulations, and current policies and procedures for the purpose of determining whether there are any deficiencies or inconsistencies therein which prohibit full compliance with the purposes and provisions of this Act and shall propose to the President not later than July 1, 1971, such measures as may be necessary to bring their authority and policies into conformity with the intent, purposes, and procedures set forth in this Act.

SEC. 104. Nothing in Section 102 or 103 shall in any way affect the specific statutory obligations of any Federal agency (1) to comply with criteria or standards of environmental quality, (2) to coordinate or consult with any other Federal or State agency, or (3) to act, or refrain from acting contingent upon the recommendations or certification of any other Federal or State agency.

SEC. 105. The policies and goals set forth in this Act are supplementary to those set forth in existing authorizations of Federal agencies.

TITLE II

COUNCIL ON ENVIRONMENTAL QUALITY

SEC. 201. The President shall transmit to the Congress annually beginning July 1, 1970, an Environmental Quality Report (hereinafter referred to as the "report") which shall set forth (1) the status and condition of the major natural, manmade, or altered environmental classes of the Nation, including, but not limited to, the air, the aquatic, including marine, estuarine, and fresh water, and the terrestrial environment, including, but not limited to, the forest, dryland, wetland, range, urban, suburban, and rural environment; (2) current and foreseeable trends in the quality, management and utilization of such environments and the effects of those trends on the social, economic, and other requirements of the Nation; (3) the adequacy of available natural resources for fulfilling human and economic requirements of the Nation in the light of expected population pressures; (4) a review of the programs and activities (including regulatory activities) of the

Federal Government, the State and local governments, and nongovernmental entities or individuals, with particular reference to their effect on the environment and on the conservation, development and utilization of natural resources; and (5) a program for remedying the deficiencies of existing programs and activities, together with recommendations for legislation.

SEC. 202. There is created in the Executive Office of the President a Council on Environmental Quality (hereinafter referred to as the "Council"). The Council shall be composed of three members who shall be appointed by the President to serve at his pleasure, by and with the advice and consent of the Senate. The President shall designate one of the members of the Council to serve as Chairman. Each member shall be a person who, as a result of his training, experience, and attainments, is exceptionally well qualified to analyze and interpret environmental trends and information of all kinds: to appraise programs and activities of the Federal Government in the light of the policy set forth in title I of this Act; to be conscious of and responsive to the scientific, economic, social, esthetic, and cultural needs and interests of the Nation; and to formulate and recommend national policies to promote the improvement of the quality of the environment.

SEC. 203. The Council may employ such officers and employees as may be necessary to carry out its functions under this Act. In addition, the Council may employ and fix the compensation of such experts and consultants as may be necessary for the carrying out of its functions under this Act, in accordance with section 3109 of title 5, United States Code (but without regard to the last sentence thereof).

SEC. 204. It shall be the duty and function of the Council--

(1) to assist and advise the President in the preparation of the Environmental Quality Report required by section 201;

(2) to gather timely and authoritative information concerning the conditions and trends in the quality of the environment both current and prospective, to analyze and interpret such information for the purpose of determining whether such conditions and trends are interfering, or are likely to interfere, with the achievement of the policy set forth in title I of this Act, and to compile and submit to the President studies relating to such conditions and trends;

(3) to review and appraise the various programs and activities of the Federal Government in the light of the policy set forth in title I of this Act for the purpose of determining the extent to which such programs and activities are contributing to the achievement of such policy, and to make recommendations to the President with respect thereto;

(4) to develop and recommend to the President national policies to foster and promote the improvement of environmental quality to meet the conservation, social, economic, health, and other requirements and goals of the Nation;

(5) to conduct investigations, studies, surveys, research, and analyses relating to ecological systems and environmental quality;

(6) to document and define changes in the natural environment, including the plant and animal systems, and to accumulate necessary data and other information for a continuing analysis of these changes or trends and an interpretation of their underlying causes;

(7) to report at least once each year to the President on the state and condition of the environment; and

(8) to make and furnish such studies, reports thereon, and recommendations with respect to matters of policy and legislation as the President may request.

SEC. 205. In exercising its powers, functions, and duties under this Act, the Council shall--

(1) consult with the Citizens' Advisory Committee on Environmental Quality established by Executive Order numbered 11472, dated May 29, 1969, and with such representatives of science, industry, agriculture, labor, conservation organizations, State and local governments and other groups, as it deems advisable; and

(2) utilize, to the fullest extent possible, the services, facilities, and information (including statistical information) of public and private agencies and organizations, and individuals, in order that duplication of effort and expense may be avoided, thus assuring that the Council's activities will not unnecessarily overlap or conflict with similar activities authorized by law and performed by established agencies.

SEC. 206. Members of the Council shall serve full time and the Chairman of the Council shall be compensated at the rate provided for Level II of the Executive Schedule Pay Rates (5 U.S.C. 5313). The other members of the Council shall be compensated at the rate provided for Level IV of the Executive Schedule Pay Rates (5 U.S.C. 5315).

SEC. 207. There are authorized to be appropriated to carry out the provisions of this Act not to exceed $300,000 for fiscal year 1970, $700,000 for fiscal year 1971, and $1,000,000 for each fiscal year thereafter.

Approved January 1, 1970.

PROTECTION AND ENHANCEMENT OF ENVIRONMENTAL QUALITY

Executive Order 11514 - March 5, 1970

By virtue of the authority vested in me as President of the United States and in furtherance of the purpose and policy of the National Environmental Policy Act of 1969 (Public Law No. 91-190, approved January 1, 1970), it is ordered as follows:

SECTION 1. *Policy.* The Federal Government shall provide leadership in protecting and enhancing the quality of the Nation's environment to sustain and enrich human life. Federal agencies shall initiate measures needed to direct their policies, plans and programs so as to meet national environmental goals. The Council on Environmental Quality, through the Chairman, shall advise and assist the President in leading this national effort.

SEC. 2. *Responsibilities of Federal agencies.* Consonant with Title I of the National Environmental Policy Act of 1969, hereafter referred to as the "Act", the heads of Federal agencies shall:

(a) Monitor, evaluate, and control on a continuing basis their agencies' activities so as to protect and enhance the quality of the environment. Such activities shall include those directed to controlling pollution and enhancing the environment and those designed to accomplish other program objectives which may affect the quality of the environment. Agencies shall develop programs and measures to protect and enhance environmental quality and shall assess progress in meeting the specific objectives of such activities. Heads of agencies shall consult with appropriate Federal, State and local agencies in carrying out their activities as they affect the quality of the environment.

(b) Develop procedures to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs with environmental impact in order to obtain the views of interested parties. These procedures shall include, whenever appropriate, provision for public hearings, and shall provide the public with relevant information, including information on alternative courses of action. Federal agencies shall also encourage State and local agencies to adopt similar procedures for informing the public concerning their activities affecting the quality of the environment.

(c) Insure that information regarding existing or potential environmental problems and control methods developed as part of research, development, demonstration, test, or evaluation activities is made available to Federal agencies, States, counties, municipalities, institutions, and other entities, as appropriate.

(d) Review their agencies statutory authority, administrative regulations, policies, and procedures, including those relating to loans, grants, contracts, leases, licenses, or permits, in order to identify any deficiencies or inconsistencies therein which prohibit or limit full compliance with the purposes and provisions of the Act. A report on this review and the corrective actions taken or planned, including such measures to be proposed to the President as may be necessary to bring their authority and policies into conformance with the intent, purposes, and procedures of the Act, shall be provided to the Council on Environmental Quality not later than September 1, 1970.

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(e) Engage in exchange of data and research results, and cooperate with agencies of other governments to foster the purposes of the Act.

(f) Proceed, in coordination with other agencies, with actions required by section 102 of the Act.

SEC. 3. *Responsibilities of Council on Environmental Quality.* The Council on Environmental Quality shall:

(a) Evaluate existing and proposed policies and activities of the Federal Government directed to the control of pollution and the enhancement of the environment and to the accomplishment of other objectives which affect the quality of the environment. This shall include continuing review of procedures employed in the development and enforcement of Federal standards affecting environmental quality. Based upon such evaluations the Council shall, where appropriate, recommend to the President policies and programs to achieve more effective protection and enhancement of environmental quality and shall, where appropriate, seek resolution of significant environmental issues.

(b) Recommend to the President and to the agencies priorities among programs designed for the control of pollution and for enhancement of the environment.

(c) Determine the need for new policies and programs for dealing with environmental problems not being adequately addressed.

(d) Conduct, as it determines to be appropriate, public hearings or conferences on issues of environmental significance.

(e) Promote the development and use of indices and monitoring systems (1) to assess environmental conditions and trends, (2) to predict the environmental impact of proposed public and private actions, and (3) to determine the effectiveness of programs for protecting and enhancing environmental quality.

(f) Coordinate Federal programs related to environmental quality.

(g) Advise and assist the President and the agencies in achieving international cooperation for dealing with environmental problems, under the foreign policy guidance of the Secretary of State.

(h) Issue guidelines to Federal agencies for the preparation of detailed statements on proposals for legislation and other Federal actions affecting the environment, as required by section 102(2)(C) of the Act.

(i) Issue such other instructions to agencies, and request such reports and other information from them, as may be required to carry out the Council's responsibilities under the Act.

(j) Assist the President in preparing the annual Environmental Quality Report provided for in section 201 of the Act.

(k) Foster investigations, studies, surveys, research, and analyses relating to (i) ecological systems and environmental quality, (ii) the impact of new and changing technologies thereon, and (iii) means of preventing or reducing adverse effects from such technologies.

SEC. 4. *Amendments of E.O. 11472.* Executive Order No. 11472 of May 29, 1969, including the heading thereof, is hereby amended:

(1) By substituting for the term "the Environmental Quality Council", wherever it occurs, the following: "the Cabinet Committee on the Environment".

(2) By substituting for the term "the Council", wherever it occurs, the following: "the Cabinet Committee".

(3) By inserting in subsection (f) of section 101, after "Budget,", the following: "the Director of the Office of Science and Technology,".

(4) By substituting for subsection (g) of section 101 the following:

"(g) The Chairman of the Council on Environmental Quality (established by Public Law 91-190) shall assist the President in directing the affairs of the Cabinet Committee."

(5) By deleting subsection (c) of section 102.

(6) By substituting for "the Office of Science and Technology", in section 104, the following: "the Council on Environmental Quality (established by Public Law 91-190)"

(7) By substituting for "(hereinafter referred to as the "Committee")", in section 201, the following: "(hereinafter referred to as the "Citizens' Committee")".

(8) By substituting for the term "the Committee", wherever it occurs, the following: "the Citizen's Committee".

RICHARD NIXON

The White House
March 5, 1970

[Filed with the Office of the Federal Register, 2:20 p.m., March 5, 1970]

Attachment 2; IM 20-6-67

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

REPORT ON GUIDELINES FOR MINIMIZING POSSIBLE SOIL EROSION FROM HIGHWAY CONSTRUCTION

(July 1, 1967)

NATURE AND SCOPE OF PROBLEM

Recent Federal legislation and executive orders have emphasized the need to conserve our natural resources. Pollution abatement, erosion control, and beautification of highway rights-of-way are major areas of concern. The control of soil and water is basic to this conservation effort; therefore, highway construction and maintenance must be continually evaluated to minimize erosion that scars the landscape and creates pollution problems.

All highway agencies recognize the detrimental effects of erosion within the highway right-of-way and give special attention in design to preventive measures where such measures are needed. The success of these measures is evidenced by the many miles of highways now serving the traveling public without serious erosion scars. Highways not properly located, designed, constructed, or maintained are at times subject to erosion and may contribute to stream pollution. Serious erosion not only results in unsightly conditions and increased maintenance costs, but sometimes causes safety hazards.

A highway built to modern standards has few erosion problems after its completion, particularly if good maintenance practices are followed. Highway builders are usually criticized because of erosion during construction, but few data exist to evaluate damages from erosion that takes place during the construction period. Good engineering demands an evaluation of the problem as a basis for imposing controls.

Problems encountered in finding feasible ways to minimize erosion are varied and complex. Several disciplines of science and engineering are required to reach an acceptable solution to most erosion problems. Adequate technical competence of both the contracting agencies and the contractors is necessary. Highway designers, project engineers, and maintenance personnel need the advice of hydrologists, hydraulic engineers, soil engineers, soil scientists, agronomists, landscape architects, and other specialists to minimize erosion problems. Emphasis must be placed on the extra cost to the contractor for correcting erosion damage resulting from poor construction practices; the economic effect of occasional pollution of stream, lakes, and water supplies; and the lower costs of maintaining the roadsides and constructed slopes of highways built to minimize erosion.

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Development and training of personnel in erosion preventive measures that should be considered in the location, design, construction, and maintenance of highway facilities must be increasingly stressed. Much research information and many practicable techniques for minimizing erosion are available in research publications and design bulletins but refresher courses and promotion of the use of these data are badly needed. Guidelines and design manuals serve an excellent purpose but they alone are not enough. Adequate technical staffs in the various highway agencies are necessary to cooperate with agencies at all governmental levels which are responsible for the prevention, abatement, and control of pollution and soil and water conservation.

The Bureau of Public Roads emphasizes erosion control on Federally financed highway construction by issuing memorandums and instructional material, by reviewing plans and specifications, by conducting schools and conferences, and by making field inspections of construction work done by State and local agencies. During the past year the Bureau of Public Roads has requested all State highway departments to review and revise, if found necessary, all sections of specifications that relate to control of erosion and pollution during or as a result of highway construction. Time will be required to inspect construction operations and evaluate the effectiveness of the States' specifications.

Direct Federal construction of highways is controlled by the Bureau of Public Roads "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (January 1961)." These specifications require that the contractor ". . . conduct and schedule his operations so as to avoid or minimize siltation of streams, lakes, and reservoirs . . ." (Article 8.3(g), p. 22). Article 102-3.6 (p. 40) requires that "During the construction of the roadway, the roadbed shall be maintained in such condition that it will be well drained at all times. Side ditches or gutters emptying from cuts to embankments or otherwise shall be so constructed as to avoid damage to embankments by erosion." Other sections of the specifications give detailed requirements to accomplish these objectives.

The policy of the Bureau of Public Roads and of the State highway agencies is well stated on page 216 of the American Association of State Highway Officials publication, "A Policy on Geometric Design of Rural Highways," 1965, as follows:

> "Erosion prevention is one of the major factors in the design, construction and maintenance of highways. Erosion can be controlled to a considerable degree by geometric design, particularly that relating to the cross section. In some respects the control is directly associated with proper provision for drainage and fitting landscape development. Effect on erosion should be considered in the location and design stages.
>
> "Erosion and maintenance are minimized largely by the use of: flat side slopes, rounded and blended with natural terrain; drainage channels designed with due regard to width, depth,

> slopes, alinement, and protective treatment; inlets located and spaced with erosion control im mind; prevention of erosion at culvert outlets; proper facilities for ground water interception; dikes, berms, and other protective devices; and protective ground covers and planting."

The quoted publication is used by both the Bureau of Public Roads and the State highway agencies as a design guide.

GUIDELINES FOR EROSION CONTROL

Although some standardization of methods for minimizing soil erosion in highway construction is possible, national guidelines for the control of erosion must necessarily be of a general nature because of the wide variation in climate, topography, geology, and soils encountered in different parts of the country. For example, erosion control must be given careful attention in the design of a highway traversing an area of rough topography, erodible soils, high and constant wind velocities, and heavy precipitation. A high degree of erosion control is required in a watershed that is the collecting area for a public water supply or a recreational facility.

Erosion control guidelines should encompass all phases of highway engineering to realize economical and effective control of erosion that might occur. These guidelines are stated under the headings: Planning and Location, Design Features, Construction Practice, Maintenance, Research and Development, and Legal Requirements and Responsibilities.

Planning and Location

Effective erosion control begins in the planning and location of a highway route. Control of water and knowledge of the soils to be encountered are basic in determining measures for preventing erosion and the movement of sediment. A highway location selected with due consideration of problems associated with these basic elements will greatly reduce erosion problems during and after construction.

The natural drainage pattern, soils and geology of the area, and manmade features that are associated with erosion and sediment should be examined for each route considered and should be a major factor in selecting the route to be used. Potential landslide areas, stream crossings and encroachments, and the magnitude of cut and fill sections should be evaluated relative to construction problems that will arise in reducing erosion and in preventing sediment and turbid water from entering streams, water supplies and irrigation systems. Preliminary soil surveys, geologic investigations, and hydrologic studies are necessary to define potential problem areas.

Cooperation with Federal, State, and local agencies having jurisdiction over water resources, soil conservation, and irrigation should begin in the planning and location stage. Technical information, data, standards, and guidelines available from all levels of other agencies are of considerable value in planning the extent of erosion-prevention measures deemed necessary and in defining problems likely to be encountered from erosion and from stream pollution by sediment, other minerals, and contaminants. Usually only limited sediment and turbidity data are available for natural streams, reservoirs, and lakes during floods. Therefore, special effort should be made by the highway agency to document the initial conditions in order to fix responsibility if claims and litigation arise after the construction has begun. Controls or limitations that may be imposed by other agencies on the construction contractor's operations should be investigated early in the planning of a highway so that necessary modifications in designs and specifications can be made before the project is advertised for bids.

Design Features

Many problems involving erosion during and after construction can be avoided by proper design. Careful selection of alinement and grace of a highway is as important as the general location. Special effort should be made to minimize disturbance of the soil. Slopes of the roadway cross sections should be based on soil stability, climatic exposure, geology, proposed landscape treatment, and maintenance procedures to be followed. The cross section should be varied, if necessary, on a particular project to minimize erosion and to facilitate safety and drainage. Generally, good landscaping and drainage design are compatible with both erosion control and safety to vehicles.

Erosion is usually caused by concentrated runoff or by the impact of rain falling on unprotected soil or unstable rock. In some areas, erosion is caused by wind or runoff from snow melt. The erosion potential should be estimated and measures to prevent erosion selected on the basis of both the effectiveness of the control measures and the consequences of the erosion. In most instances the designer has a wide range of choice in type of erosion-control measures; but intensity of rainfall, the season of the year, severity of erosion, and cost must all be considered in the design selected. Design for erosion control is complex and should be done by trained specialists.

Some features of a highway are more vulnerable to erosion than others and therefore, require special consideration at the design stage. Guidelines for the treatment of erosion in several of these critical areas and for the design of erosion and sediment control structures follow:

a. Earth cut and fill slopes -- Severe erosion of earth slopes is usually caused by a concentration of storm water flowing from the roadway section or from the area at the top of cut slopes down unprotected embankments or other slopes. Preventing concentration of water in these critical areas is essential. Channels, ditches, berms, or shoulder dikes for diverting water to satisfactory outfalls should be constructed at appropriate locations early in the construction of the project. Rainfall on cut and fill slopes will cause erosion to varying degrees, depending on the intensity of rainfall, the type of soil, the degree of slope, the length of the exposed surface, the climatic exposure, and the effectiveness of the vegetative or other protective cover. Benches or terraces, enclosed drainage systems, or the mulching or covering of the soil with various materials may be required to reduce slope erosion. The need for and the type of protection should be determined in the design stage. Protective treatment of cut and fill slopes, whether temporary or permanent, should be a part of the grading contract and should be applied insofar as practicable as the grading operations progress.

b. Waterways or channels -- Surface channels, natural or manmade, are usually the most economical means of collecting and disposing of runoff in highway construction. Such channels, however, if not designed properly, can create serious erosion problems.

Care in the location and the design of roadway channels is necessary both for efficient drainage and for traffic safety. A primary design principle is to provide channels with flat side slopes and wide bottoms, protected adequately to avoid soil erosion. If designs, such as rectangular concrete channels, are needed to accommodate flood flows, the channel should be placed at a safe distance from the traveled way or a barrier erected to protect traffic. Sometimes drainage easements are necessary to provide a well designed and safe channel.

Protective linings for channels and streams can be very expensive and a considerable percentage of the highway dollar is spent on this item of work. Special effort must be made to develop the lowest-cost type of erosion protection for the particular location. Channel design and protective treatments are discussed in Hydraulic Design Series No. 4, "Design of Roadside Drainage Channels," published by the Bureau of Public Roads and available from the Government Printing Office. Field manuals and publications of the Soil Conservation Service also contain valuable channel design information. Several research projects are in progress to develop more economical and satisfactory channel linings.

c. Structures for erosion control -- Special structures other than open channels are used in highway construction to convey water and to control erosion. Grade-control structures, energy dissipators, special culverts, and various types of pipelines have been used for this purpose. These structures are usually costly and are recommended for use only after it has been determined that vegetation, rock, or other types of treatment will not control the anticipated erosion. As a general rule, designers should avoid large accumulations of flowing water and use a type of erosion protection that keeps velocities to a minimum. Such a guideline will minimize erosion and avoid the need for costly erosion-control structures. Where such structures are required, designs should receive careful attention since these structures are vulnerable to failure or are ineffective if not properly designed and installed. Erosion caused by high velocity flows at the outlet of highway structures deserves particular attention.

Most highway departments have standard designs for various types of erosion-control structures. Considerable use is made of Soil Conservation Service and Bureau of Reclamation publications containing designs for this purpose. If unusual and expensive designs are contemplated, model testing is often desirable to study performance. Models frequently show needed modifications or refinements in design that improve performance and effect considerable saving in the construction costs.

d. Detention or sedimentation basins -- Small dams can be placed in a waterway to form reservoirs or basins for detaining flood water and trapping sediment caused by erosion. Such dams can be of the temporary or permanent type, depending on the need. A highway embankment can serve as a dam for this purpose at some locations. The Soil Conservation Service and several highway departments have developed special culvert designs that control degrading of stream channels and detain sediment and flood water.

Dams for trapping sediment must be properly located and designed because failure during a major flood could have consequences far greater than most sediment problems created by highway construction. Health and safety hazards, methods of disposing of the trapped sediment and the future flood potential must also be evaluated.

e. Soil treatment -- The use of grasses or other plants for landscaping and erosion control which are not ecologically adapted to a particular area usually results in poor erosion control and increased maintenance. Every effort should be made to use ecologically adapted vegetation that will survive in a particular area with minimum maintenance. Proven soil conservation practices, including the use of mulches and temporary protective measures, are all important in developing permanent vegetative covers. Irrigation is often required to establish ground cover or maintain a safisfactory stand in semi-arid areas. With further development, dust palliatives may be effective in erosion control, particularly in arid areas where wind erosion is a problem. Agronomists who have a technical knowledge of soils and plants of the area can be very helpful in suggesting methods and kinds of treatments. Cooperation with local offices of the Soil Conservation Service in developing new methods and hardy strains of grass or other plants to resist erosion has been found beneficial by the State highway departments.

Construction Practice

The plans, specifications, and special provisions of a highway contract should be explicit in showing the location, scope, and manner of performing erosion-control measures. If deficiencies in the design or performance of these measures are discovered during construction, the engineer should take immediate steps for correction. Measures left to the discretion of the engineer should be as few as practicable and the method of measurement and payment for such work should be stated in the contract.

Proper planning and scheduling of construction operations are major factors in controlling erosion. A construction schedule that meets the highway agency's requirements for erosion control should be made a part of the construction project proposal or a schedule should be submitted by the contractor for approval by the engineer. Sufficient erosion-control measures should be included as a part of the initial grading contract. On subsequent paving or other contracts, the project engineer should not allow construction operations which contribute to soil erosion.

Permanent soil protection and drainage facilities should be completed as early as practicable, particularly intercepting channels and similar controls that will divert runoff from work areas and unprotected soil. Sections of bare earth and the length of their exposure to erosion should be minimized by proper scheduling and limiting the work areas with consideration of the program of the contractor and climatic conditions. Temporary protection such as fiber mats, plastic, straw, dust palliatives, and fast-growing grasses may be required in some areas to prevent erosion from water or wind on newly completed slopes. Partially completed drainage structures should be inspected carefully during construction to prevent unnecessary erosion and to avoid damage to these structures.

Special precautions should be taken in the use of construction equipment to prevent operations which promote erosion. Wheel tracks from heavy equipment are expecially vulnerable to erosion from the concentration of water. Fording of streams with equipment should be kept to a minimum, and in locations where frequent crossings of streams are contemplated, temporary bridges or culverts should be constructed if the sediment created is detrimental to fish and wildlife, water supplies, or irrigation systems. Plans by a contractor for work roads showing the method of construction, erosion-control measures, and restoration should be approved by the engineer.

Although disturbance by highway construction of streams, lakes, or reservoirs should be avoided, drainage structures, channel changes, and embankment encroachemnts are sometimes necessary in building a highway. Specifications or special provisions should include controls for the contractor's operation in performing work in these areas, particularly in conforming with regulations of water resource and fish and wildlife agencies. Some types of construction and stream conditions may necessitate the construction of diversion dikes or other protective measures to avoid sediment problems. Embankment slopes that encroach on stream channels should be adequately protected against erosion. Where practicable, a protective area of vegetative cover should be left or established between the highway embankment and adjacent stream channels. At some locations, temporary or permanent training works placed in the channel can reduce bed or bank scour.

Areas for borrow pits and waste disposal should be selected with full consideration of erosion control during borrow operations, and the final treatment or restoration of the area. When it becomes necessary to locate such areas near or in stream channels, special precautions should be taken to minimize erosion and accompanying sediment problems. Regardless of the responsibility for the selection of borrow areas, whether it be the contractor or the contracting agency, plans of operation and of restoration, or cleanup and shaping should be approved by the engineer.

Before borrow or disposal operations are begun, plans for the control of drainage water must include measures to keep sediment from entering streams. Diversion channels, dikes, and sediment traps may be used for this purpose. Good topsoil from the borrow pit area should be saved for use in restoring the excavated area. Final restoration of borrow or waste disposal areas should include grading, establishment of vegetative cover, or other necessary treatments that will blend the area into the surrounding landscape. The restored area should be well drained unless approval is given to convert the pit areas into lakes for fish and wildlife, recreation, stock water, or irrigation.

Specifications should include adequate control for the prevention of grass and brush fires since burned-over areas are usually highly vulnerable to erosion. In areas where a severe fire hazard exists, fire equipment should be available for ready use. The contract should provide for suspending fire-hazardous operations at the direction of the engineer or local fire control agency and compliance with local fire regulations should be required.

Maintenance

Preventive maintenance built into the highway in the location, design, and construction phases will save many dollars in maintenance costs. Experts in soil conservation, agronomy, and drainage should be available to assist in maintenance inspections and to recommend appropriate erosion-control measures.

Inspections of drainage and erosion-control measures should be made shortly after completion of construction to locate and correct deficiencies before they develop into major problems. Deficiencies in design or in construction procedures should be discussed with the engineering staff so that similar deficiencies can be prevented on future projects. Coordination of responsibilities for erosion-control measures among design, construction, and maintenance departments needs to be emphasized.

Because of the rapid turnover of maintenance personnel, frequent training schools should be conducted in maintenance techniques, including methods of making inspections, care or management of vegetative covers and plants, and measures to prevent and correct erosion.

Maintenance records should give sufficient detail to permit analysis of maintenance problems, particularly those related to erosion control. With the advent of the computer, coding of maintenance costs for the various elements of the highway could serve in tabulating and analyzing data for use in making changes in design and construction that will reduce erosion problems and lower maintenance costs.

Research and Development

Although several State highway departments in cooperation with the Bureau of Public Roads, the Department of Agriculture, and other agencies have developed economical and practicable measures to control erosion, additional research is needed to improve present methods and provide even more economical and effective means for preventing erosion both during and subsequent to construction.

Methods and sequence of construction require further study in many areas of the country. Weather conditions, soil characteristics, and types of effective erosion-control measures vary, thus requiring a different approach to the erosion problem. Investigations are needed to develop protective covers and treatment of soils to avoid expensive sodding practices and to reduce the cost of channel linings. Further development in the use of dust palliatives could prove beneficial in areas subject to wind erosion.

Data on the amount of sediment transported to streams due to erosion during the construction of a highway are very limited. The increase of sediment in a stream due to highway construction and its estimated damage over that produced under natural conditions are not well defined. Such information is necessary to evaluate properly the extent of controls needed for the control of sediment during the construction of a highway.

The Department of Agriculture, through its Agricultural Research Service and Soil Conservation Service, has developed methods to prevent soil erosion that are effective in specific areas of the country. Many of their designs and procedures are now being used in highway construction. An additional cooperative effort between the State highway departments and the Department of Agriculture, especially in developing vegetation and in improving soil conservation methods, should be actively promoted. This cooperation will provide assurance that the best methods for preventing erosion are being used.

Legal Requirements and Responsibilities

Legal requirements and governmental responsibilities in matters related to water vary throughout the States. The responsibility for damage to upstream and downstream property must be considered in highway design, particularly with respect to flooding, erosion, and sediment. Statutes in some States establish rigid controls in matters related to fish and wildlife, pollution of streams and water supplies, irrigation, and diversions of natural stream courses. It is the policy of the Bureau of Public Roads to participate with Federal highway funds in construction of highway projects that meet the requirements of other Federal, State, and local agencies, if such requirements are in accordance with good design practice and are determined to be the responsibility of the highway agency.

CONCLUSIONS

The following measures should be taken to minimize soil erosion from highway construction:

a. The highway should be located to avoid trouble areas where erosion or landslides may occur.

b. The design of the highway should provide adequate surface and subsurface drainage.

c. Areas where erosion will occur should be anticipated and suitable slope and channel protection specified in the construction contract.

d. Construction operations should be controlled by adequate specifications and special provisions and by capable supervision.

e. Maintenance forces should recognize deficiencies in drainage and erosion-prevention works, and take action to correct both potential and actual deficiencies before they develop into major problems.

f. Research should be conducted to improve erosion-control methods, and liasion between design and research engineers and maintenance forces should be continuous.

g. Erosion-control specialists should be on the highway engineering and maintenance staffs to provide competent direction to erosion-control efforts.

h. The highway agencies should prepare specifications for drainage and erosion-control measures adapted to conditions and materials found within the State.

These guidelines are intended to aid in the preparation of appropriate construction specifications and design procedures. They are not meant to be directives that apply in all areas and under all conditions. Effort to prevent erosion during highway construction and on the completed highway is rewarding both in the enhanced beauty of the highway and in the contribution of highway agencies to conservation of our land and water and to the reduction of pollution in our waterways.

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS
WASHINGTON, D.C. 20591

April 30, 1970

INSTRUCTIONAL MEMORANDUM 20-3-70
32-36

SUBJECT: Prevention, Control, and Abatement of Water Pollution Resulting from Soil Erosion

Instructional Memorandums 20-3-66 (June 7, 1966), 20-2-67 (May 24, 1967), 20-6-67 (December 29, 1967), and 20-1-68 (March 6, 1968) were issued to implement Executive Order 11258 (November 17, 1965), revised as Executive Order 11288 (July 2, 1966) and superseded by Executive Order 11507 (February 4, 1970) which pertained to the furtherance of the purpose and policy of the Federal Water Pollution Control Act, as amended, which is administered by the Federal Water Pollution Control Administration under direction of the Secretary of the Interior.

The "Guidelines for Minimizing Possible Soil Erosion From Highway Construction, July 1, 1967," joint report of the Department of Transportation and the Department of Agriculture was attached to IM 20-6-67. This report covered the minimum erosion control guidelines that are needed during planning and location, design, construction and maintenance and commented on areas needing further research and development.

In the "Construction Practice" section of the cited guidelines it was pointed out that "If deficiencies in the design or performance of these measures are discovered during construction, the Engineer should take immediate steps for correction." And further that, "Temporary protection such as fiber mats, plastic, straw, dust palliatives, and fast-growing grasses may be required in some areas to prevent erosion from water or wind on newly completed slopes."

Based on our evaluation of contractor's present practices we consider further emphasis in this area is needed. To strengthen this area, all future direct Federal and Federal-aid contracts shall include specific temporary pollution control provisions in the contract documents and provide for direct payment for the work. Accordingly, there is attached a special provision for temporary water pollution control which the States and direct Federal contract administrators shall include in all projects authorized for advertising 60 days after the date of this instructional memorandum. Modifications may be made in this special provision to meet individual State or project conditions. This special provision will give the Engineer authority to take immediate and effective action to control water pollution.

Since these temporary pollution control measures are frequently made necessary by unforeseen work conditions, they normally are not included as bid items. In the future, the P. S. & E. assemblies and contract provisions for all direct Federal and Federal-aid projects involving earthwork shall contain provisions for a reasonable estimated sum for payment for work performed for temporary pollution control.

To permit timely action by the Engineer and the contractor, individual change orders will not be required on either direct Federal or Federal-aid contracts so long as the basis of payment and cost documentation is clearly established and the cost of the work involved is within the total amount originally set up for temporary pollution control in the contract provisions.

It is expected that liberal use of temporary pollution control measures will be made to ensure that soil erosion is kept to a practicable minimum.

We emphasize that permanent project pollution control features must be performed at the earliest practicable time consistent with good construction practices and that temporary pollution control features are meant to be supplementary measures and are not meant to be performed in lieu of permanent pollution control features included in the contract.

It is expected that on existing construction contracts, the States and direct Federal contract administrators will follow the concepts of these provisions insofar as possible under the specifications in effect when the current contract was let. It is recognized that under most current specifications, the payment for temporary pollution control features is incidental to other work. Where erosion problems are occurring on existing contracts, adequate control measures that are necessary to improve the conditions on the project should be used. If project conditions have developed requiring the application of extensive or unusual measures not reasonably foreseeable at the time of bidding, funding under extra work or change order should be processed expeditiously.

The BPR inspection program should include requirements to determine that positive steps are being taken by the contractor to comply with contract specifications to prevent erosion, pollution and siltation to the maximum extent practicable.

/s/

R. R. Bartelsmeyer
Director of Public Roads

Enclosure

SPECIAL PROVISION

TEMPORARY PROJECT WATER POLLUTION CONTROL (SOIL EROSION)

DESCRIPTION:

This work shall consist of temporary control measures as shown on the plans or ordered by the Engineer during the life of the contract to control water pollution, through use of berms, dikes, dams, sediment basins, fiber mats, netting, gravel, mulches, grasses, slope drains, and other erosion control devices or methods.

The temporary pollution control provisions contained herein shall be coordinated with the permanent erosion control features specified elsewhere in the contract to the extent practical to assure economical, effective and continuous erosion control throughout the construction and postconstruction period.

MATERIALS:

a. Mulches may be hay, straw, fiber mats, netting, wood cellulose, corn or tobacco stalks, bark, corn cobs, wood chips, or other suitable material acceptable to the Engineer and shall be reasonably clean and free of noxious weeds and deleterious materials.

b. Slope drains may be constructed of pipe, fiber mats, rubble, portland cement concrete, bituminous concrete, plastic sheets, or other material acceptable to the Engineer that will adequately control erosion.

c. Grass shall be a quick growing species (such as rye grass, Italian rye grass, or cereal grasses) suitable to the area providing a temporary cover which will not later compete with the grasses sown later for permanent cover.

d. Fertilizer and soil conditioners shall be a standard commercial grade acceptable to the Engineer.

e. Others as specified by the Engineer.

PRECONSTRUCTION CONFERENCE:

At the preconstruction conference or prior to the start of the applicable construction, the contractor shall submit for acceptance his schedules for accomplishment of temporary and permanent erosion control work, as are applicable for clearing and grubbing; grading; bridges and other structures at watercourses; construction; and paving. He shall also submit for acceptance his proposed method of erosion control on haul roads and borrow pits and his plan for disposal of waste materials. No work shall be started until the erosion control schedules and methods of operations have been accepted by the Engineer.

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CONSTRUCTION REQUIREMENTS:

The Engineer has the authority to limit the surface area of erodible earth material exposed by clearing and grubbing, the surface area of erodible earth material exposed by excavation, borrow and fill operations and to direct the contractor to provide immediate permanent or temporary pollution control measures to prevent contamination of adjacent streams or other watercourses, lakes, ponds, or other areas of water impoundment. Such work may involve the construction of temporary berms, dikes, dams, sediment basins, slope drains, and use of temporary mulches, mats, seeding or other control devices or methods as necessary to control erosion. Cut slopes shall be seeded and mulched as the excavation proceeds to the extent considered desirable and practicable.

The contractor will be required to incorporate all permanent erosion control features into the project at the earliest practicable time as outlined in his accepted schedule. Temporary pollution control measures will be used to correct conditions that develop during construction that were not foreseen during the design stage; that are needed prior to installation of permanent pollution control features; or that are needed temporarily to control erosion that develops during normal construction practices, but are not associated with permanent control features on the project.

Where erosion is likely to be a problem, clearing and grubbing operations should be so scheduled and performed that grading operations and permanent erosion control features can follow immediately thereafter if the project conditions permit; otherwise temporary erosion control measures may be required between successive construction stages. Under no conditions shall the surface area of erodible earth material exposed at one time by clearing and grubbing, exceed 750,000 square feet without approval by the Engineer.

The Engineer will limit the area of excavation, borrow and embankment operations in progress commensurate with the contractor's capability and progress in keeping the finish grading, mulching, seeding, and other such permanent pollution control measures current in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion control measures shall be taken immediately to the extent feasible and justified.

Under no conditions shall the amount of surface area of erodible earth material exposed at one time by excavation, borrow or fill within the right-of-way exceed 750,000 square feet without prior approval by the Engineer.

The Engineer may increase or decrease the amount of surface area of erodible earth material to be exposed at one time by clearing and grubbing, excavation, borrow and fill operations as determined by his analysis of project conditions.

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